

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Hiroyoshi Tomita, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, and Tatsuya Kanda, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan have invented certain new and useful improvements in

SEMICONDUCTOR DEVICE RECONCILING
DIFFERENT TIMING SIGNALS

of which the following is a specification : -

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

Transmitted herewith for filing under 37 C.F.R. §1.53(b) is the patent application of
for(s): Hiroyoshi TOMITA; and Tatsuya KANDA

SEMICONDUCTOR DEVICE RECONCILING DIFFERENT TIMING SIGNALS

Specification and Claims (66 pages)

- ☒ 25 sheets of drawings
☒ Newly executed Declaration and Power of Attorney
☒ Return Receipt Postcard
☒ An assignment of the invention to FUJITSU LIMITED with accompanying PTO-1595 Form
☒ A certified copy of Japanese Patent Application No. 10-022257 filed: February 3, 1998
— A verified stmt. to establish small entity status under 37 C.F.R. §1.9 and 37 C.F.R. §1.27

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Respectfully submitted,

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1 TITLE OF THE INVENTION

 SEMICONDUCTOR DEVICE RECONCILING DIFFERENT
TIMING SIGNALS

5 BACKGROUND OF THE INVENTION

 1. Field of the Invention

 The present invention relates to
semiconductor devices, and particularly relates to a
semiconductor device which acquires data signals based
10 on a data-strobe signal.

 2. Description of the Related Art

 According to some proposed schemes,
semiconductor devices such as those functioning as
memory devices may acquire address signals in
15 synchronism with a clock signal, and input or output
data signals in synchronism with a data-strobe signal
different from the clock signal with an aim of
achieving a stable data input/output at high speed.

 Fig.1 is a timing chart showing operations
20 of a semiconductor device which acquires data in
synchronism with a data-strobe signal. This device
operations and timings thereof are conceived by the
inventors for the sake of showing an example.

 Fig.1 shows a case in which data acquisition
25 is performed based on a DDR (double data rate) scheme
acquiring data in synchronism with both rising edges
and falling edges of a data-strobe signal. A clock
signal CLK is shown at the top, and a data-strobe
signal DS is illustrated in the middle. At the bottom
30 in the figure is demonstrated a data signal DQ which
is acquired in synchronism with the data-strobe signal
DS. The example of Fig.1 demonstrates data-
acquisition timings of a burst-write operation where
the burst length is set to 4 to write 4-bit data D0-D3
35 consecutively.

 At a first rising edge (clk1) of the clock
signal CLK, a write command and a write address WA1

1 indicative of a start address are input. The write
command is decoded by a command decoder, and is
supplied to the write-command latch of the
semiconductor device, which in turn supplies a write-
5 enable signal. The write-enable signal activates
buffers to receive the data-strobe signal DS and the
data signal DQ, respectively. The data signal DQ
received by one of the buffers is acquired (latched)
by a latch in synchronism with the data-strobe signal
10 DS received by the other one of the buffers. Since it
takes some time to generate the write-enable signal
and activate the buffers, a time period t_{DSS} from the
input of the write command (clk1) to the timing of a
first rising edge of the data-strobe signal DS needs
15 to be at least 3 ns, for example.

 Data D0 is latched at the first rising edge
of the data-strobe signal DS, and data D1 is latched
at an immediately following falling edge. A next
write address WA2 is internally generated at the
20 second rising edge (clk2) of the clock signal CLK.
Data D2 is then latched at an immediately following
rising edge of the data-strobe signal DS, and data D3
is latched at a subsequent falling edge.

 In the DDR scheme, the data D0 and D1 are
25 latched by two different latches. Immediately after
the data D1 is latched, the data D0 and D1 are
simultaneously supplied in parallel to the internal
circuit of the semiconductor device. Accordingly,
data is input at half the cycles of the strobe signal,
30 while the internal circuit operates at the same cycles
as that of the strobe signal. The write address at
which the data D0 and D1 are stored is WA1. Further,
immediately after the latching of the data D3, the
data D2 and D3 are simultaneously supplied in parallel
35 to the internal circuit of the semiconductor device.
In this case, the write address is WA2.

 In the semiconductor device as described

1 above, the data-strobe signal DS input by the user
preferably has a timing thereof permitting a tolerable
timing margin.

5 Fig.2 is a timing chart of a data-
acquisition operation in which the first rising edge
of a data-strobe signal is delayed by one clock cycle
behind the input of a write command.

10 At a first rising edge (clk1) of the clock
signal CLK, a write command and a write address WA1
are input from an external source. The first rising
edge of the data-strobe signal DS is delayed relative
to the input of the address WA1 by one clock cycle,
appearing at a timing clk2. This rising edge of the
data-strobe signal DS is used to latch data D0, and a
15 following falling edge is used to latch data D1. A
next write address WA2 is internally generated at the
second rising edge (clk2) of the clock signal CLK.
Data D2 is then latched at a following rising edge of
the data-strobe signal DS appearing at a timing clk3,
20 and data D3 is latched at an immediately following
falling edge.

30 Upon the latching of the data D1, the data
D0 and D1 are supplied to the internal circuit of the
semiconductor device in parallel. The write address
for the data D0 and D1 is WA1. A write address which
was internally generated by the semiconductor device
at an immediately preceding timing (clk2) is, however,
WA2. Because of this, a simplistic structure which
stores an incoming write address in a conventional
30 buffer results in the write address WA1 being replaced
by the write address WA2 by the time when the data D0
and D1 are supplied to the internal circuit.

35 In order to avoid this, the write addresses
WA1 and WA2 need to be successively stored in a shift
register or the like, for example. In such a
configuration, the write address WA1 would have to be
read at a timing when the data D0 and D1 are supplied

1 to the internal circuit, and the write address WA2
would have to be read at a timing at which the data D2
and D3 are supplied to the internal circuit.

5 Implementing address buffers via shift
registers is effective where a clock signal and a
data-strobe signal are input at such timings as shown
in Fig.2, but is not applicable to a case where these
signals are input at such timings as shown in Fig.1.
10 Since shift registers need some time to complete shift
operations thereof, the shift registers used as the
address buffers may not be able to output proper
addresses at a time when a write operation of data D0
and D1 starts in Fig.1.

15 When the time period tDSS has such a length
as shown in Fig.1, it is required to use a write
address acquired at a timing immediately prior to the
supply of data to the internal circuit. That is, when
the data D0 and D1 are supplied to the internal
circuit, for example, the write address acquired
20 immediately before is WA1, so that the write address
WA1 needs to be provided to the internal circuit along
with the data D0 and D1. In contrast, when the time
period tDSS is such a period as shown in Fig.2, the
write address WA2 acquired at an immediately preceding
25 timing should not be used, but the write address WA1
that is acquired at a timing previous to this
preceding timing should be used with respect to the
data D0 and D1, as described above.

30 If the data-strobe signal is to permit a
tolerable timing margin, there is a need to attend to
control of address-read operations so as to read an
appropriate address from an address buffer at an
appropriate timing.

35 Accordingly, there is a need for a
semiconductor device which allows a data-strobe signal
to be provided within a tolerable timing margin when
acquiring data in synchronism with the data-strobe

1 signal.

Further, a semiconductor device employing a data-strobe signal acquires data and addresses in synchronism with respective timing signals. That is, data is acquired in response to a data-strobe signal, and addresses are acquired in response to a clock signal. Because of a timing difference between a data acquisition and an address acquisition, it is difficult for an internal circuit to perform accurate data processing and data transfer at high speed by matching data with correct addresses.

Accordingly, there is a need for a semiconductor device which can process data and addresses at high speed when the data and addresses are acquired at different timings.

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a semiconductor device which can satisfy the need described above.

It is another and more specific object of the present invention to provide a semiconductor device which allows a data-strobe signal to be provided within a tolerable timing margin when acquiring data in synchronism with the data-strobe signal.

It is yet another object of the present invention to provide a semiconductor device which can process data and addresses at high speed when the data and addresses are acquired at different timings.

In order to achieve the above objects according to the present invention, a semiconductor device which receives addresses in synchronism with a clock signal and receives data in synchronism with a strobe signal includes address-latch circuits, a first control circuit which selects one of the address-latch circuits in sequence in response to the clock signal,

1 and controls the selected one of the address-latch
circuits to latch a corresponding one of the addresses
in response to the clock signal, and a second control
circuit which selects one of the address-latch
5 circuits in sequence in response to the strobe signal,
and controls the selected one of the address-latch
circuits to output a corresponding one of the
addresses in response to the strobe signal.

According to one aspect of the present
10 invention, the semiconductor device as described above
further includes data-latch circuits, each of which
latches a corresponding datum of the data in
synchronism with the strobe signal, and outputs the
corresponding datum of the data in synchronism with
15 the strobe signal.

According to another aspect of the present
invention, the semiconductor device as described above
is such that the data-latch circuits operate in
response to a write-enable signal which is generated
20 in response to a write command to the semiconductor
device.

According to another aspect of the present
invention, the semiconductor device as described above
is such that said write-enable signal controls said
25 first control circuit and said second control circuit
to operate for a predetermined time period after
receiving the write command.

According to another aspect of the present
invention, the semiconductor device as described above
30 is such that the first control circuit includes a
first frequency divider configured to divide a
frequency of the clock signal, and selects one of said
address-latch circuits in sequence by using the
frequency-divided clock signal from said first
35 frequency divider, and said second control circuit
includes a second frequency divider configured to
divide a frequency of the strobe signal, and selects

1 one of said address-latch circuits in sequence by
using the frequency-divided strobe signal from said
second frequency divider.

According to another aspect of the present
5 invention, the semiconductor device as described above
further includes an increment-latch circuit which
latches one of the addresses in synchronism with the
clock signal, and an address-generation circuit which
increments the one of the addresses latched by said
10 increment-latch circuit by 1, and supplies the
incremented address to said address-latch circuits,
wherein each of said address-latch circuits configured
so as to be capable of selecting the corresponding one
of the addresses externally provided or the
15 incremented address supplied from said address-
generation circuit for the latching operation thereof.

According to another aspect of the present
invention, the semiconductor device as described above
is such that said data-latch circuit comprises a first
20 data-latch circuit which latches a corresponding datum
of the data in synchronism with a rising edge of the
strobe signal, and a second data-latch circuit which
latches a corresponding datum of the data in
synchronism with a falling edge of the strobe signal.

25 In the semiconductor device which receives
the addresses in synchronism with the clock signal and
receives data in synchronism with the strobe signal,
the address-latch circuits latch the addresses in
response to the clock signal, and outputs the
30 addresses in synchronism with the strobe signal.
During this operation, the addresses are written one
after another into a successively selected one of the
address-latch circuits, and are read therefrom
successively. This makes it possible to
35 simultaneously supply the data and the corresponding
addresses to the internal circuit in synchronism with
the strobe signal. An appropriate data-write

1 operation is thus achieved regardless of the timing of
the data-strobe signal as long as this timing falls
within a tolerable margin.

5 According to another aspect of the present
invention, a semiconductor device which receives
addresses in synchronism with a clock signal and
receives data in synchronism with a strobe signal
includes data-latch circuits, a first control circuit
10 which selects one of said data-latch circuits in
sequence in response to the strobe signal, and
controls the selected one of said data-latch circuits
to latch a corresponding datum of the data in response
to the strobe signal, and a second control circuit
15 which selects one of said data-latch circuits in
sequence in response to the clock signal, and controls
the selected one of said data-latch circuits to output
a corresponding datum of the data in response to the
clock signal.

20 According to another aspect of the present
invention, the semiconductor device as described above
further includes an address-latch circuit which
latches the addresses in sequence in synchronism with
the clock signal, and outputs the addresses in
synchronism with the clock signal.

25 According to another aspect of the present
invention, the semiconductor device as described above
is such that the data-latch circuits operate in
response to a write-enable signal which is generated
in response to a write command to the semiconductor
30 device.

35 According to another aspect of the present
invention, the semiconductor device as described above
is such that the write-enable signal controls said
first control circuit and said second control circuit
to operate for a predetermined time period after
receiving the write command.

According to another aspect of the present

1 invention, the semiconductor device as described above
is such that said first control circuit includes a
first frequency divider configured to divide a
frequency of the strobe signal, and selects one of
5 said data-latch circuits in sequence by using the
frequency-divided strobe signal from said first
frequency divider, and said second control circuit
includes a second frequency divider configured to
divide a frequency of the clock signal, and selects
10 one of said data-latch circuits in sequence by using
the frequency-divided clock signal from said second
frequency divider.

According to another aspect of the present
invention, the semiconductor device as described above
15 further includes an address-generation circuit which
increments one of the addresses latched by said
address-latch circuit, and supplies the incremented
address to said address-latch circuit, wherein said
address-latch circuit is configured so as to be
20 capable of selecting the addresses externally provided
or the incremented address supplied from said address-
generation circuit for the latching operation thereof.

According to another aspect of the present
invention, the semiconductor device as described above
25 is such that each of said data-latch circuits includes
a first latch which latches a corresponding datum of
the data in synchronism with a rising edge of the
strobe signal, and a second latch which latches a
corresponding datum of the data in synchronism with a
30 falling edge of the strobe signal.

According to another aspect of the present
invention, the semiconductor device as described above
is such that said address-latch circuit includes a
delay circuit which delays output timings of the
35 addresses by a predetermined number of cycles of the
clock signal.

According to another aspect of the present

1 invention, the semiconductor device as described above
further includes an address buffer, wherein said
address-latch circuit(s) supplies the addresses to
said address buffer without a clock-cycle delay during
5 a read operation.

In the semiconductor device which receives
the addresses in synchronism with the clock signal and
receives data in synchronism with the strobe signal,
the data-latch circuits latch the data in response to
10 the strobe signal, and outputs the data in synchronism
with the clock signal. During this operation, the
data are written one datum after another into a
successively selected one of the data-latch circuits,
and are read therefrom successively. This makes it
15 possible to simultaneously supply the data and the
corresponding addresses to the internal circuit in
synchronism with the clock signal. An appropriate
data-write operation is thus achieved regardless of
the timing of the data-strobe signal as long as this
20 timing falls within a tolerable margin.

Other objects and further features of the
present invention will be apparent from the following
detailed description when read in conjunction with the
accompanying drawings.

25

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a timing chart showing operations
of a semiconductor device which acquires data in
synchronism with a data-strobe signal;

30

Fig.2 is a timing chart of a data-
acquisition operation in which a first rising edge of
a data-strobe signal is delayed by one clock cycle
behind inputting of a write command;

35

Fig.3 is a block diagram showing a first
embodiment of a semiconductor memory device according
to the present invention;

Figs.4A through 4I are timing charts showing

1 input/output timings of latches;

Fig.5 is a circuit diagram showing a circuit configuration of frequency divider;

5 Fig.6 is a circuit diagram showing a circuit configuration of a latch-input-clock generator;

Fig.7 is a circuit diagram showing a circuit structure of a latch-output-clock generator;

Fig.8 is a circuit diagram showing a circuit structure of the latches and an address buffer;

10 Fig.9 is a circuit diagram showing a circuit structure of an increment latch;

Fig.10 is a circuit diagram showing a circuit structure of a write-pulse/column-selection-pulse generator;

15 Fig.11 is a circuit diagram showing details of inter-connections between a command decoder, a write-command latch, a burst-length-measurement counter, a mode register, and a clock generator;

20 Fig.12 is a block diagram showing a second embodiment of a semiconductor memory device according to the present invention;

Fig.13 is a timing chart for explaining operations of the semiconductor memory device of Fig.12 in the case of the shortest tDSS;

25 Fig.14 is a timing chart for explaining operations of the semiconductor memory device of Fig.12 in the case of the longest tDSS;

Fig.15 is a circuit diagram showing a circuit configuration of a latch-input-clock generator;

30 Fig.16 is a circuit diagram showing another configuration of the latch-input-clock generator;

Fig.17 is a circuit diagram showing a circuit structure of a latch-output-clock generator;

35 Fig.18 is a circuit diagram showing another configuration of the latch-output-clock generator;

Fig.19 is a circuit diagram showing circuit

1 structures of a data latch, a shift register, and a
data latch;

Fig.20 is a circuit diagram showing a
relevant portion of an internal-clock generator which
5 generates timing signals used for controlling a 1.5-
clock-cycle delay;

Fig.21 is a circuit diagram showing circuit
structures of an address latch, a shift register, and
an address buffer;

10 Fig.22 is a circuit diagram showing a
circuit structure of a write-pulse/column-selection-
pulse generator;

Fig.23 is a timing chart for explaining
timing relations between a clock signal, a data-strobe
15 signal, and data-write timings when the time period
tDSS has a relatively narrow margin;

Fig.24 is a block diagram of a third
embodiment of the present invention; and

Fig.25 is a block diagram of a fourth
20 embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, embodiments of the present
invention will be described with reference to the
25 accompanying drawings.

Fig.3 is a block diagram showing a first
embodiment of a semiconductor memory device according
to the present invention. In particular, the figure
shows a schematic diagram of a DDR-type synchronous
30 DRAM.

A semiconductor memory device 10 includes a
data-input buffer 11, a data-strobe-input buffer 12,
an address buffer 13, a data latch 14, a shift
register 15, a data latch 16, a frequency divider 17,
35 a frequency divider 18, a latch-output-clock generator
19, a latch-input-clock generator 20, an internal-
clock generator 21, a command decoder 22, a write-

1 command latch 23, an increment latch 24, an address
generator 25, a latch 26, a latch 27, an address
buffer 28, a write amplifier 29, a write amplifier 30,
a write-pulse/column-selection-pulse generator 31, a
5 predecoder 34, a predecoder 35, an odd-numbered-cell
array 36, an even-numbered-cell array 37, a sense
amplifier 38, a sense amplifier 39, a column decoder
40, a column decoder 41, a burst-length-measurement
counter 42, a read amplifier 43, a read amplifier 44,
10 a clock generator 501, a mode register 502, a
parallel-to-serial conversion unit 503, and an output
buffer 504.

The semiconductor memory device 10 inputs an
address in synchronism with a clock signal CLK, and
15 acquires a data signal DQ in synchronism with a data-
strobe signal DS. In practice, each of data and an
address are comprised of a plurality of bits. In the
following description, however, a circuit structure
will be shown with respect to only one of these bits
20 for the sake of clarity of explanation.

In the semiconductor memory device 10
according to the first embodiment of the present
invention, the latches 26 and 27 connected in parallel
latch two consecutive addresses input thereto. The
25 latches 26 and 27 latch the input addresses in
synchronism with the clock signal CLK under the
control of the latch-input-clock generator 20 when
these input addresses are supplied from the address
buffer 13, which receives the addresses in synchronism
30 with an internal clock signal iCLK. Alternatively,
the latches 26 and 27 latch internal addresses iAdd
generated by the increment latch 24 and the address
generator 25. Further, the latches 26 and 27 supply
the latched addresses to the address buffer 28 in
35 synchronism with the data-strobe signal DS under the
control of the latch-output-clock generator 19. The
input addresses have a first one thereof latched by

1 the latch 26, and are latched thereafter by the latch
27 and the latch 26 in turn. When the latched
addresses are supplied to the address buffer 28, a
first one is supplied from the latch 26, and the
5 subsequent data are supplied from the latch 27 and the
latch 26 in turn.

A configuration as described above can cope
with the case in which the time period tDSS is the
shortest as shown in Fig.1 as well as the case in
10 which the time period tDSS is the longest as shown in
Fig.2.

In the case of the shortest tDSS as shown in
Fig.1, the latch 26 latches the address WA1 in
synchronism with the clock signal, and outputs the
15 address WA1 at an edge of the data-strobe signal
corresponding to the timing at which the data D1 is
supplied. Then, the latch 27 latches the address WA2,
and the address WA2 is output at an edge of the data-
strobe signal corresponding to a timing of the data
20 D3.

In the case of the longest tDSS as shown in
Fig.2, the address WA1 is latched by the latch 26,
and, then, the address WA2 is latched by the latch 27.
At an edge of the data-strobe signal corresponding to
25 a timing of the data D1, the address WA1 is output
from the latch 26. Then, the address WA2 is output
from the latch 27 at an edge of the data-strobe signal
corresponding to a timing of the data D3.

Further, the latches 26 and 27 output
30 addresses to the address buffer 28 in synchronism with
the data-strobe signal. Likewise, in synchronism with
the data-strobe signal, the shift register 15 and the
data latch 16 output data in parallel to the write
amplifiers 29 and 30. Because of this, the internal
35 circuit operating in synchronism with the data-strobe
signal can process data signals and address signals at
high speed with sufficient accuracy. Here, the

1 internal circuit refers to a set of circuits provided
at stages subsequent to the address buffer 28, the
shift register 15, and data latch 16, and includes the
predecoders 34, 35, the write amplifiers 29, 30, the
5 sense amplifiers 38, 39, the column decoders 40, 41,
etc.

In the first embodiment of the present
invention described above, the input addresses are
stored in the two latches 26 and 27 which are provided
10 in parallel. The addresses stored in the latches 26
and 27 are then subsequently read at appropriate
timings, thereby coping with any timings of the data-
strobe signal DS supplied within a tolerable timing
margin ranging from the shortest tDSS to the longest
15 tDSS.

In what follows, operations of the
semiconductor memory device 10 will be described.

The command decoder 22 receives a command
20 Comm (i.e., a combination of control signals such as
/RAS, /CAS, /CS, /WE, and the like) in synchronism
with the clock signal CLK, and decodes the same to
generate a write signal wrpz and a CAS signal when the
command is a write command. These signals are
25 comprised of HIGH pulses. The CAS signal is also
generated in response to other commands such as a read
command. When the CAS signal is supplied to the clock
generator 501, an external-timing-pulse signal extpnz
is generated as a one-shot HIGH pulse. After this,
30 the clock generator outputs HIGH pulses as an
internal-timing-pulse signal intpnz in synchronism
with the internal clock signal iCLK until the burst-
length-measurement counter outputs a burst-end signal
endz (L level). The burst-length-measurement counter
35 42 measures the burst length. The burst-length-
measurement counter 42 is reset by the
external-timing-pulse signal extpnz, and, then, counts

1 the internal-timing-pulse signal intpnz as many times
as the burst length, which is stored in the mode
register 502 in advance. When the counting is
completed, the burst-end signal endz is output to the
5 write-command latch 23 in response to the internal
clock signal iCLK. The write-command latch 23 outputs
a write-enable signal wrtz that is at a HIGH level in
response to the write signal wrpz sent from the
command decoder 22, and resets the write-enable signal
10 wrtz when receiving an endpz signal (L level) from the
burst-length-measurement counter 42.

The internal-timing-pulse signal intpnz and
the external-timing-pulse signal extpnz are supplied
to the latch-input-clock generator 20 to control
15 generation of latch-input clocks. External-latch-
input clocks extplz and extprz are used for
controlling acquisition of external addresses by the
latches 26 and 27, and internal-latch-input clocks
intplz and intrpz are used for controlling acquisition
20 of internal addresses by the latches 26 and 27.

The write-enable signal wrtz is supplied to
the data-input buffer 11 and the data-strobe-input
buffer 12 so as to enable these buffers. The write-
enable signal wrtz is also supplied to the frequency
25 divider 17 and the frequency divider 18, thereby
prompting a start of frequency-division operations of
the frequency dividers 17 and 18.

The write-enable signal wrtz is output from
the write-command latch 23 only for a predetermined
30 duration following the input of the write command.
this makes it possible to make the frequency dividers
17 and 18 operate only with respect to a predetermined
number of cycles.

The data-input buffer 11 receives the data
35 signal DQ when being enabled by the write-enable
signal wrtz. The data-strobe-input buffer 12 enabled
by the write-enable signal wrtz receives the data-

1 strobe signal DS, and outputs a DS1 signal having a
 rising edge synchronized with a rising edge of the DS
 signal and a /DS1 signal rising in synchronism with a
5 falling edge of the DS signal. The DS1 signal is
 supplied to the data latch 14, the frequency divider
 17, and the latch-output-clock generator 19, and the
 /Ds1 signal is supplied to the shift register 15 and
 the data latch 16.

 The data signal DQ received by the data-
10 input buffer 11 is stored in the data latch 14 in
 synchronism with the DS1 signal. A next one of the
 data signal DQ is stored in the data latch 16 in
 synchronism with the /DS1 signal. The data signal DQ
15 stored in the data latch 14 is further stored in the
 shift register 15 in synchronism with the data-strobe
 signal /DS1. When data D0 and D1 are successively
 supplied, therefore, the shift register 15 stores the
 data D0, and the data latch 16 stores the data D1.
 Then, the shift register 15 and the data latch 16
20 output the data D0 and D1 in parallel to the write
 amplifiers 29 and 30, respectively, in synchronism
 with the /DS1 signal. The data latches 14 and 16 and
 the shift register 15 together form a serial-to-
 parallel conversion unit 505.

25 The data stored in the shift register 15 and
 the data latch 16 are provided to the internal
 circuit, and, in detail, are supplied to the sense
 amplifiers 38 and 39 via the write amplifiers 29 and
 30, respectively. Operation timings of the write
30 amplifiers 29 and 30 are controlled by the write-
 amplifier-activation signal WRT supplied from the
 write-pulse/column-selection-pulse generator 31.
 Column addresses for selecting sense amplifiers to
 store data therein when the data is supplied to the
35 sense amplifiers 38 and 39 are supplied from the
 predecoders 34 and 35 to the column decoders 40 and
 41, respectively, where the column addresses are

1 decoded. The data stored in the sense amplifiers 38
and 39 are then supplied and stored in the odd-
numbered-cell array 36 and the even-numbered-cell
array 37, respectively. The odd-numbered-cell array
5 36 and the even-numbered-cell array 37 are comprised
of DRAM-memory-cell arrays, for example. Each cell
array includes a plurality of memory cells arranged in
a matrix and comprised of memory-cell capacitors and
access transistors, a plurality of word-lines arranged
10 in a row direction for the purpose of selecting the
access transistors, and a plurality of bit lines
arranged in a column direction for the purpose of
conveying data from the memory cell via the access
transistors to the sense amplifiers and writing the
15 data of the sense-amplifiers into the memory cells.

Further, the odd-numbered-cell array and the
even-numbered cell array respectively correspond to
odd addresses and even addresses. When the address
WA1 of Fig.1 is an odd address, for example, the data
20 D0 is written into memory cells selected from the odd-
numbered-cell array, and the data D1 is written into
memory cells selected from the even-numbered-cell
array.

During a read operation, on the other hand,
25 data of selected memory cells in the odd-numbered-cell
array 36 and the even-numbered-cell array 37 are
supplied to and amplified by the sense amplifiers 38
and 39, respectively. Then, data is output from the
sense amplifiers selected by the column decoders 40
30 and 41, and is supplied in parallel to the read
amplifiers 43 and 44, respectively. The data of the
read amplifiers 43 and 44 are converted into serial
data by the parallel-to-serial conversion unit 503.
The serial data is then output to outside from the
35 data pins DQ via the output buffer 504.

The clock signal CLK is supplied to the
internal-clock generator 21. The internal-clock

1 generator 21 in turn generates the internal clock
signal iCLK which is synchronized with the external
clock signal CLK.

5 The frequency divider 17 divides a frequency
of the data-strobe signal DS1 in response to the
write-enable signal wrtz, and generates a frequency-
divided-data-strobe signal ds2x. Similarly, the
frequency divider 18, upon receiving the write-enable
signal wrtz, divides a frequency of the internal clock
10 signal iCLK to generate a frequency-divided-clock
signal clk2z.

The latch-output-clock generator 19
generates latch-output clocks ds2px and ds2pz based on
the data-strobe signal DS1 and the frequency-divided-
15 data-strobe signal ds2x. The latch-output clocks
ds2px and ds2pz are pulse signals, and become HIGH in
turn at falling edges of the data-strobe signal DS.
That is, each of them becomes HIGH at every other
falling edge of the data-strobe signal DS.

20 The latch-output clock ds2px controls
timings of address output of the latch 26, and the
latch-output clock ds2pz controls timings of address
output of the latch 27. In this manner, addresses are
output from the latch 26 and the latch 27 in turn.

25 The latch-input-clock generator 20 receives
the external-timing-pulse signal extpnz, which is the
one-short-pulse signal supplied from the clock
generator 501 in response to a command input, and
outputs the same as either the external-latch-input
30 clock extplz or the external-latch-input clock extprz
according to whether the frequency-divided-clock
signal clk2z is HIGH or LOW. In a burst-write
operation, the latch-input-clock generator 20 receives
the internal-timing-pulse signal intpnz from the clock
35 generator 501 after receiving the external-timing-
pulse signal extpnz. Then, the latch-input-clock
generator 20 outputs the internal-timing-pulse signal

1 intpnz as either the internal-latch-input clock intplz
or the internal-latch-input clock intrpz according to
whether the frequency-divided-clock signal clk2z is
HIGH or LOW.

5 The latch 26 latches an address signal Add
supplied from the address buffer 13 when the external-
latch-input clock extprz is HIGH. Also, the latch 26
latches an internal address signal iAdd supplied from
the address generator 25 when the internal-latch-input
10 clock intrpz is HIGH. Then, the latched address
signal is supplied to the address buffer 28 when the
latch-output clock ds2px is HIGH.

 The latch 27 latches an address signal Add
supplied from the address buffer 13 when the external-
15 latch-input clock extplz is HIGH. Also, the latch 27
latches an internal address signal iAdd supplied from
the address generator 25 when the internal-latch-input
clock intplz is HIGH. Then, the latched address
signal is supplied to the address buffer 28 when the
20 latch-output clock ds2pz is HIGH.

 The address signal is supplied from the
address buffer 28 to the predecoders 34 and 35. Based
on a timing of a column-selection pulse csp supplied
from the write-pulse/column-selection-pulse generator
25 31, the predecoders 34 and 35 attends to predecoding
processing. Decoded address signals obtained as a
result of predecoding are supplied to the column
decoders 40 and 41. The column decoders 40 and 41
indicate data-write addresses by further decoding the
30 results of predecoding.

 The increment latch 24 and the address
generator 25 are provided for the purpose of
automatically generating internal addresses during a
burst operation. In a burst operation, the increment
35 latch 24 latches external addresses supplied from the
address buffer 13 in synchronism with the external-
timing-pulse signal extpnz supplied from the clock

1 generator 501. The address generator 25 adds 1 to the
address output from the increment latch 24 to generate
an internal address iAdd, and sends the internal
address iAdd to the increment latch 24 and the latches
5 26 and 27. The increment latch 24 latches the
internal address in response to the internal-timing-
pulse signal intpnz from the clock generator 501.
After this, acquisition of an internal address by the
increment latch 24 and an address increment by the
10 address generator 25 are repeated as many times as the
burst length minus 1. Here, the burst length is
specified in the mode register 502.

The write-pulse/column-selection-pulse
generator 31 receives the data-strobe signal DS1 and
15 the internal clock signal iCLK, and outputs the write-
amplifier-activation signal WRT and the column-
selection signal csp in accordance with an operation
mode specified by the write-enable signal wrtz.
Namely, when a write operation is specified (wrtz =
20 H), the write-pulse/column-selection-pulse generator
31 outputs the write-amplifier-activation signal WRT
and the column-selection signal csp at a predetermined
timing in response to the data-strobe signal DS1.
When a read operation is specified (wrtz = L), the
25 write-pulse/column-selection-pulse generator 31
generates the column-selection signal csp in response
to the internal-timing-pulse signal intpnz and the
external-timing-pulse signal extpnz, and puts the
write-amplifier-activation signal WRT in an
30 deactivated state (i.e., fixed at a L level) so as to
stop operations of the write amplifiers 29 and 30.

Figs.4A through 4I are timing charts showing
input/output timings of the latches 26 and 27.

These figures show the clock signal CLK, the
35 frequency-divided-clock signal clk2z, the external-
timing-pulse signal extpnz, the external-latch-input
clock extprz, the external-latch-input clock extplz,

1 the data-strobe signal DS, the frequency-divided-data-
strobe signal ds2x, the latch-output clock ds2px, and
the latch-output clock ds2pz in this order from the
top to the bottom. Figs.4A through 4I show a case in
5 which the burst length is 4, and an address is input
along with a write command at each rising edge of the
clock signal CLK. As previously described, the latch
26 acquires the first external address signal based on
the external-latch-input clock extprz, and outputs the
10 same based on the latch-output clock ds2px. In the
case of the latch 27, the next external address signal
is acquired based on the external-latch-input clock
extplz, and the same is output based on the latch-
output clock ds2pz.

15 As is apparent from the figures, the address
acquired by the latch 26 in response to the external-
latch-input clock extprz is supplied to the address
buffer 28 always earlier than the other address that
is acquired one clock later by the latch 27 in
20 response to the external-latch-input clock extplz.
Also, two addresses (A1, A2) latched at successive
rising edges of the clock CLK are stored in the
separate latches 26 and 27, respectively, so that the
first address (A1) is retained even when the second
25 address is input. Further, a data-output timing of
parallel data output from the shift register 15 and
the data latch 16 and an address-output timing of
addresses output from the latches 26 and 27 are based
on the data-strobe signal. Because of this, the
30 internal circuit can match data with a corresponding
address by using the data-strobe signal as a
reference. In Figs.2A through 2I, the address A1
latched by the latch 26 in response to the first
rising edge of the clock signal CLK is output to the
35 address buffer 28 at a falling edge of the data-strobe
signal indicated by t=1. Matching the address A1, the
data D0 and D1 respectively latched by the shift

1 register 15 and the data latch 16 are also output to
the write amplifiers 29 and 30 at the falling edge of
the data-strobe signal at the time $t=1$. Namely,
although different timing signals (i.e., the clock
5 signal and the data-strobe signal) are used for
establishing synchronizations when the semiconductor
device acquires an address and data, the internal
circuit can process the address and data in
synchronism with the common timing signal (i.e., data-
10 strobe signal in this example).

According to the first embodiment of the
present invention as described above, the two latches
26 and 27 provided in parallel, rather than a shift
register, store the input addresses, and output the
15 same at respective appropriate timings. In this
manner, the data-strobe signal DS can be provided at
any timing within the timing margin between the
shortest tDSS and the longest tDSS while an
appropriate operation is insured.

20 In what follows, a description will be
provided with regard to a configuration of each
element which is relevant to latch-input/output
timings of address signals according to the present
invention.

25 Fig.5 is a circuit diagram showing a circuit
configuration of the frequency divider 17 or 18.

The frequency divider 17 or 18 of Fig.5
includes NAND circuits 101 through 109, inverters 110
through 113, a PMOS transistor 114, and NMOS
30 transistors 115 and 116. The write-enable signal wrtz
is supplied to the NAND circuits 101, 103, 106, and
109. This makes sure that the frequency divider of
Fig.5 operates only when the write-enable signal wrtz
is HIGH. When the data-strobe signal DS1 or the
35 internal clock signal iCLK is input while the write-
enable signal wrtz is HIGH, a frequency-divided output
signal changes to a HIGH level in response to the

1 first rising edge of the input signal, and, then, the
input signal is subjected to 1/2-frequency division to
be output as the frequency-divided-data-strobe signal
ds2x or the frequency-divided-clock signal clk2z,
5 respectively. When the write-enable signal wrtz is
LOW, the output of the frequency divider is fixed to
HIGH. Frequency-division operations per se are well
within the scope of ordinary skill in the art, and a
description thereof will be omitted.

10 Fig.6 is a circuit diagram showing a circuit
configuration of the latch-input-clock generator 20.

The latch-input-clock generator 20 of Fig.6
includes NAND circuits 121 through 127 and inverters
128 through 132. When the write-enable signal wrtz is
15 HIGH, a signal having the same phase as the frequency-
divided-clock signal clk2z is supplied via the
inverter 132 and the NAND circuit 121 to one input of
the NAND circuit 124. The other input of the NAND
circuit 124 receives the external-timing-pulse signal
20 extpnz. During periods when the frequency-divided-
clock signal clk2z is HIGH, the external-timing-pulse
signal extpnz is output as the external-latch-input
clock extplz. Further, an inverse of the frequency-
divided-clock signal clk2z is supplied via the NAND
25 circuit 123 to one input of the NAND circuit 125. The
other input of the NAND circuit 125 receives the
external-timing-pulse signal extpnz. During periods
when the frequency-divided-clock signal clk2z is LOW,
therefore, the external-timing-pulse signal extpnz is
30 output as the external-latch-input clock extprz. In
an example of Figs.4A through 4I, the external-timing-
pulse signal extpnz is output in synchronism with
rising edges of the clock pulse CLK, and the
frequency-divided-clock signal clk1z starts from an L
35 level and changes between H and L at each rising edge
of the clock. In the example of Figs.4A through 4I in
a write operation, therefore, the latch-input-clock

1 generator first supplies an extprz-signal pulse to the
latch 26, and, then, supplies an extplz-signal pulse
to the latch 27. In this manner, the external
addresses are latched first by the latch 26 and next
5 by the latch 27. When the write-enable signal wrtz is
LOW, the external-timing-pulse signal extpnz is output
as the external-latch-input clocks extplz and extprz
at all times.

In the case of a burst-write operation, the
10 internal-timing-pulse signal intpnz is supplied as
many times as the burst length after the external-
timing-pulse signal extpnz is first supplied in
synchronism with a rising edge of the clock at which
the write command is input.

15 When the internal-timing-pulse signal intpnz
is supplied, the internal-timing-pulse signal intpnz
is output as the latch-input clock intplz during time
periods when the frequency-divided-clock signal clk2z
is HIGH. During time periods when the frequency-
20 divided-clock signal clk2z is LOW, on the other hand,
the internal-timing-pulse signal intpnz is output as
the latch-input clock intprz. In the case of a burst-
write operation, the external-timing-pulse signal
extpnz is supplied during a period when the frequency-
25 divided-clock signal clk2z is LOW, so that the latch-
input-clock generator 20 outputs the external-latch-
input clock extprz. In response, the latch 26 latches
an external address Add. After the frequency-divided
clock changes to HIGH, the internal-timing-pulse
30 signal intpnz is supplied, so that the latch-input-
clock generator 20 outputs the internal-latch-input
clock intplz. In response, the latch 27 latches an
internal address iAdd generated by the address
generator 25. Where the write-enable signal wrtz is
35 LOW, the latch-input clocks intplz and intprz become
identical to the internal-timing-pulse signal intpnz.

Fig.7 is a circuit diagram showing a circuit

1 structure of the latch-output-clock generator 19.

The latch-output-clock generator 19 of Fig.7 includes NAND circuits 141 through 145, inverters 146 through 152, and capacitors C1 and C2. The data-strobe signal DS1 input to the inverter 146 is delayed by a series of delay elements comprised of the inverters 147 through 149 and the capacitors C1 and C2. The NAND circuit 141 and the inverter 150 perform an AND operation between an inverse of the data-strobe signal DS1 and the delayed data-strobe signal, thereby generating a pulse signal becoming HIGH at falling edges of the data-strobe signal DS1. This pulse signal is output as the latch-output clock ds2px via the NAND circuits 143 and 145 when the frequency-divided-data-strobe signal ds2x is HIGH. When the frequency-divided-data-strobe signal ds2x is LOW, on the other hand, the pulse signal is output as the latch-output clock ds2pz via the NAND circuits 142 and 144. Where the write-enable signal wrtz is LOW, both the latch-output clock ds2pz and ds2px are fixed to HIGH.

In the example of Figs.2A through 2I, the frequency-divided-data-strobe signal ds2x becomes HIGH in response to a first rising edge of the data-strobe signal DS, so that the latch-output-clock generator 19 first outputs the latch-output clock ds2px. In response, the latch 26 supplies the address latched therein to the address buffer 28. Then, the latch-output-clock generator 19 outputs the latch-output clock ds2pz, which prompts the latch 27 to supply the latched address to the address buffer 28.

Fig.8 is a circuit diagram showing a circuit structure of the latches 26 and 27 as well as the address buffer 28.

The latches 26 and 27 in Fig.8 have the same configuration, and include inverters 161 through 168 and transfer gates 169 through 172. Each of the

1 transfer gates 169 through 172 is comprised of a PMOS
transistor and an NMOS transistor. When the external-
latch-input clock extplz (or extprz) becomes HIGH, the
transfer gate 169 is opened, so that the external
5 address signal Add from the address buffer 13 (Fig.3)
is latched by a latch comprised of the inverters 164
and 165. The address signal stored in the latch is
supplied to the address buffer 28 when the latch-
output clock ds2pz (or ds2px) becomes HIGH so as to
10 open the transfer gate 172.

Where the internal-latch-input clock intplz
(or intprz) is supplied, an incremented internal
address signal iAdd supplied from the address
generator 25 (Fig.3) is latched by a latch comprised
15 of the inverters 167 and 168. The incremented address
signal iAdd is then stored in the latch made up from
the inverters 164 and 165 at a timing when the latch-
input clock intplz (or intprz) becomes HIGH. The
address signal stored in the latch is supplied to the
20 address buffer 28 via a transfer gate 172 when the
gate is opened during a HIGH period of the latch-
output clock ds2pz (or ds2px).

The address buffer 28 includes inverters 181
through 185. The address buffer 28 stores the address
25 signal supplied serially from either the latch 26 or
the latch 27, and outputs the address signal and an
inverse thereof.

When the write-enable signal wrtz is LOW
(i.e., in a read operation), the latch-input clocks
30 extplz and extprz prompt the latching of the address
signal Add, or the latch-input clocks intplz and
intprz trigger the latching of the address signal
iAdd. As previously described in connection with
Fig.7, the address signal latched in the latch 26 or
35 27 is immediately supplied to the address buffer
during a read operation since the latch-output clocks
ds2pz and ds2px are HIGH. In this manner, the

1 configuration described above insures that only a
minimum time period is necessary before supplying an
address output subsequent to the input of a read
command.

5 Fig.9 is a circuit diagram showing a circuit
structure of the increment latch 24.

The increment latch 24 of Fig.9 includes
inverters 201 through 209 and transfer gates 210
through 212. Each of the transfer gates 210 through
10 212 is made up from a PMOS transistor and an NMOS
transistor. When the external-timing-pulse signal
extpnz becomes HIGH during a burst-write operation,
the transfer gate 210 is opened, so that the external
address signal Add is stored as a start address in a
15 latch comprised of the inverters 206 and 207. The
address signal stored in the latch is supplied to the
address generator 25 via the inverters 208 and 209.

As the internal-timing-pulse signal intpnz
is subsequently supplied, the incremented internal
20 address signal iAdd supplied from the address
generator 25 (Fig.3) is latched by a latch comprised
of the inverters 204 and 205. The incremented
internal address signal iAdd is then stored in the
latch made up from the inverters 206 and 207 at a
25 timing when the internal-timing-pulse signal intpnz
becomes HIGH. Until the burst operation is completed,
the internal address iAdd from the address generator
25 is stored in the latch comprised of the inverters
206 and 207 in response to the internal-timing-pulse
30 signal.

Fig.10 is a circuit diagram showing a
circuit structure of the write-pulse/column-selection-
pulse generator 31.

The write-pulse/column-selection-pulse
35 generator 31 includes OR circuits 511, 512, AND
circuits 513-515, an inverter 516, fixed-delay
circuits 517 and 518 for timing adjustment, and a

1 pulse-width-adjustment unit 520.

The write-pulse/column-selection-pulse generator 31 generates HIGH pulses as the write-amplifier-activation signal WRT and the column-selection pulse csp in synchronism with the data-strobe signal DS1 when the write-enable signal wrtz is HIGH, i.e., when the write operation is engaged. When the write-enable signal wrtz is LOW as in a read operation, the write-pulse/column-selection-pulse generator 31 generates a HIGH pulse as the column-selection pulse csp and fixes the write-amplifier-activation signal WRT to a LOW level in synchronism with the internal-timing-pulse signal intpnz and the external-timing-pulse signal extpnz.

15 When the write-enable signal wrtz is HIGH, one input of the AND circuit 513 receives a LOW-level signal via the inverter 516. Because of this, signals originating from the external-timing-pulse signal extpnz and the internal-timing-pulse signal intpnz are blocked by the AND circuit 513. Also, the write-enable signal wrtz that is HIGH is supplied to one input of the AND circuit 514. The AND circuit 514 thus permits a passage of the data-strobe signal DS1 having a timing thereof adjusted by the fixed-delay circuit 518. This data-strobe signal is changed into pulses by the pulse-width-adjustment unit 520, and is output as the write-amplifier-activation signal WRT and the column-selection pulse csp. In a sense, the AND circuit 514 serves to output the signal /DS1 which corresponds to a first falling edge of the data-strobe signal DS after the write-enable signal wrtz becomes HIGH. When the write-enable signal wrtz is LOW (i.e., during a read operation), the AND circuit 515 has one input thereof at a LOW level so as to output a signal fixed to a LOW level as the write-amplifier-activation signal WRT. This deactivates the write amplifiers 29 and 30 (Fig.3). Since the AND circuit 514 has one

1 input thereof at a LOW level, the AND circuit 514
prevents the passage of the data-strobe signal DS1.
Since one input of the AND circuit 513 is HIGH because
of the LOW level of the write-enable signal wrtz, the
5 AND circuit 513 outputs the internal-timing-pulse
signal intpnz or the external-timing-pulse signal
extpnz having a timing thereof adjusted by the fixed-
delay circuit 517. The output from the AND circuit
513 is subjected to signal-shape adjustment by the
10 pulse-width-adjustment unit 520, and is output as the
column-selection pulse csp.

Signal-output timings of the
write-amplifier-activation signal WRT and the column-
selection pulse csp during the write operation are
15 adjusted by the fixed-delay circuit 518. This timing
adjustment makes sure that the write amplifiers 29 and
30 are activated after the parallel data is output
from the shift register 15 and the data latch 16 and
that the predecoders 34 and 35 are activated after an
20 address corresponding to the write data is output from
the address generator 33.

A signal-output timing of the column-
selection pulse csp during the read operation is
adjusted by the fixed-delay circuit 517. This
25 adjustment is to insure that the predecoders 34 and 35
are activated at such a timing as to meet an address
that is output by the address generator 33 at an
earlier timing than in a write operation.

Fig.11 is a circuit diagram showing details
30 of inter-connections between the command decoder 22,
the write-command latch 23, the burst-length-
measurement counter 42, the mode register 502 and the
clock generator 501.

The command decoder 22 receives a command in
35 synchronism with an edge of the internal clock signal
iCLK, and decodes the command which is defined as a
combination of various control signals such as /CAS,

1 /RAS, /CS, /WE, and the like. When the command Comm
is a write command, the command decoder 22 outputs the
write signal wrpz and the CAS signal that are both
HIGH. The clock generator 501 includes a rising-edge-
5 to-pulse conversion circuit 531 and AND circuits 532
and 533. The rising-edge-to-pulse conversion circuit
531 outputs the external-timing-pulse signal extpnz
that is HIGH when the CAS signal is supplied. The
burst-length-measurement counter 42 includes a counter
10 534, an inverter 535, and a flip-flop circuit 536.
The counter 534 is reset by the external-timing-pulse
signal extpnz supplied from the clock generator 501.
Because of this, a Q output of the flip-flop 536
(i.e., the burst-end signal endz) becomes HIGH in
15 response to a falling edge of the internal clock
signal iCLK. The burst-end signal endz at the HIGH
level is supplied to one input of the AND circuit 532
of the clock generator 501, so that the AND circuit
532 outputs the internal clock signal iCLK without any
20 change as it is supplied to the other input thereof.
The AND circuit 533 receives at one input thereof the
CAS signal that is HIGH, and, thus, outputs the
internal clock signal iCLK as the internal-timing-
pulse signal intpnz. The counter 534 of the burst-
25 length-measurement counter 42 counts pulses of the
internal-timing-pulse signal intpnz supplied from the
clock generator 501 until the count reaches the burst
length set in the mode register 502. When the count
is completed, the counter 534 outputs a HIGH level.
30 In response, the burst-end signal endz becomes LOW.
The change to LOW in the burst-end signal endz results
in the AND gate 532 blocking the internal clock signal
iCLK, thereby stopping the internal-timing-pulse
signal intpnz from being output.
35 The write-command latch 23 includes a latch
538 and an inverter 537. The write-command latch 23
outputs the write-enable signal wrtz that is HIGH when

1 the write signal wrpz of a HIGH level is supplied.
When the count of the intpnz-signal pulses by the
burst-length-measurement counter 42 is completed so as
to change the burst-end signal endz to LOW, the write-
5 command latch 23 resets the write-enable signal wrtz
to LOW.

Fig.12 is a block diagram showing a second
embodiment of a semiconductor memory device according
to the present invention. In Fig.12, the same
10 elements as those of Fig.3 are referred to by the same
numerals, and a description thereof will be omitted.

A semiconductor memory device 50 of Fig.12
includes the data-input buffer 11, the data-strobe-
input buffer 12, the address buffer 13, the frequency
15 divider 17, the frequency divider 18, the command
decoder 22, the write-command latch 23, the address
generator 25, the address buffer 28, the write
amplifier 29, the write amplifier 30, the write-
pulse/column-selection-pulse generator 31, the
20 predecoder 34, the predecoder 35, the odd-numbered-
cell array 36, the even-numbered-cell array 37, the
sense amplifier 38, the sense amplifier 39, the column
decoder 40, the column decoder 41, the burst-length-
measurement counter 42, the read amplifier 43, the
25 read amplifier 44, the clock generator 501, the mode
register 502, the parallel-to-serial conversion unit
503, and the output buffer 504, all of which are
included in the configuration of Fig.3. The
semiconductor memory device 50 further includes a data
30 latch 51, a shift register 52, a data latch 53, data
latch 54, a shift register 55, a data latch 56, a
delay circuit 57, a latch-input-clock generator 58, a
latch-output-clock generator 59, a internal-clock
generator 60
35 address latch 61, and a shift register 62.

In the first embodiment previously
described, the address signal is latched in

1 synchronism with the clock signal CLK, and is supplied
from the latches to the internal circuit in
synchronism with the data-strobe signal DS, thereby
5 matching timings between the address and the data. In
the second embodiment, on the other hand, the address
signal is kept synchronized with the clock signal CLK,
and the data signal latched in synchronism with the
data-strobe signal DS is supplied from latches to the
10 internal circuit in synchronism with the clock signal
CLK in order to align timings between the address and
the data.

In detail, the address signal Add supplied
to the address buffer 13 is latched by the address
latch 61 at a rising edge of the clock signal CLK.
15 After this, the shift register 62 delays the address
signal Add by 1.5 cycles in time, so that the latched
address is supplied to the address buffer 28 1.5
cycles after the input of the address signal Add. No
matter when the data-strobe signal DS is provided
20 within a time margin between the shortest tDSS and the
longest tDSS, the address is delayed by 1.5 cycles.
Data-write operations, therefore, start 1.5 cycles
after the input of a command (which occurs at a timing
of address input).

25 In what follows, operations of the
semiconductor memory device 50 will be described with
regard to a case in which tDSS is the shortest and a
case in which tDSS is the longest.

Fig.13 is a timing chart for explaining
30 operations of the semiconductor memory device 50 in
the case of the shortest tDSS. It should be noted
that Fig.13 is provided for the purpose of
explanation, and is not intended to show exact details
of signal delays introduced by circuit elements.

35 With reference to Figs.12 and 13, where the
shortest tDSS is employed, a write command is input,
and an external write address WA1 is latched by the

1 address latch 61 in response to a rising edge (clk1)
of the clock signal CLK. Data D0 of the data signal
DQ is then latched by the data latch 51 in response to
a rising edge of the data-strobe signal DS. Further,
5 a following falling edge of the data-strobe signal DS
prompts the data latch 53 to latch data D1. At the
same time, the data D0 stored in the data latch 51 is
transferred to the shift register 52.

In response to a next rising edge (clk2) of
10 the clock signal CLK, a write address WA2 is latched
by the address latch 61. When this happens, the
writes address WA1, which was previously supplied, is
transferred to and stored in the shift register 62.
Data D2 of the data signal DQ is then latched by the
15 data latch 54 in response to a rising edge of the
data-strobe signal DS. Further, a following falling
edge of the data-strobe signal DS prompts the data
latch 56 to latch data D3. At the same time, the data
D2 stored in the data latch 54 is transferred to the
20 shift register 55.

Concurrently with the operations described
above, a data-write operation with respect to the
write address WA1 is started 1.5 cycles after the
input of the write address WA1 (i.e., at a timing
25 clk2.5). Namely, the write address WA1 is supplied
from the shift register 62 to the address buffer 28,
and the data D0 of the shift register 52 and the data
D1 of the data latch 53 are supplied to the write
amplifier 29 and the write amplifier 30, respectively.

30 Following to this, a data-write operation
with respect to the write address WA2 is started 1.5
cycles after the input of the write address WA2 (i.e.,
at a timing clk3.5). Namely, the write address WA2 is
supplied from the shift register 62 to the address
35 buffer 28, and the data D2 of the shift register 55
and the data D3 of the data latch 56 are supplied to
the write amplifier 29 and the write amplifier 30,

1 respectively.

 Fig.14 is a timing chart for explaining
operations of the semiconductor memory device 50 in
the case of the longest tDSS. It should be noted that
5 Fig.14 is provided for the purpose of explanation, and
is not intended to show exact details of signal delays
introduced by circuit elements.

 With reference to Figs.12 and 14, where the
longest tDSS is employed, a write command is input,
10 and an external write address WA1 is latched by the
address latch 61 in response to a rising edge (clk1)
of the clock signal CLK. Further, responding to a
next rising edge (clk2) of the clock signal CLK, the
address latch 61 latches a write address WA2. As the
15 latter latching operation is performed, the write
address WA1, which was previously latched, is
transferred to and stored in the shift register 62.

 When the write address WA2 is latched by the
address latch 61, data D0 of the data signal DQ is
20 latched by the data latch 51 in response to a rising
edge of the data-strobe signal DS. Further, a
following falling edge of the data-strobe signal DS
prompts the data latch 53 to latch data D1. At the
same time, the data D0 stored in the data latch 51 is
25 transferred to the shift register 52.

 Concurrently with the operations described
above, a data-write operation with respect to the
write address WA1 is started 1.5 cycles after the
input of the write address WA1 (i.e., at a timing
30 clk2.5). Namely, the write address WA1 is supplied
from the shift register 62 to the address buffer 28,
and the data D0 of the shift register 52 and the data
D1 of the data latch 53 are supplied to the write
amplifier 29 and the write amplifier 30, respectively.

35 Subsequent to the above operations, data D2
of the data signal DQ is latched by the data latch 54
in response to a rising edge of the data-strobe signal

1 DS. Further, a following falling edge of the data-
strobe signal DS prompts the data latch 56 to latch
data D3. At the same time, the data D2 stored in the
data latch 54 is transferred to the shift register 55.

5 A data-write operation with respect to the
write address WA2 is started 1.5 cycles after the
input of the write address WA2 (i.e., at a timing
clk3.5). Namely, the write address WA2 is supplied
from the shift register 62 to the address buffer 28,
10 and the data D2 of the shift register 55 and the data
D3 of the data latch 56 are supplied to the write
amplifier 29 and the write amplifier 30, respectively.

In this manner, the second embodiment of the
present invention keeps the address signal in
15 synchronism with the clock signal CLK, and, upon
receiving the data signal in synchronism with the
data-strobe signal DS, supplies the data signal at
appropriate timings synchronized with the clock signal
CLK. These timings may be set to an end of a
20 predetermined clock-cycle period starting from the
input of a data-write address. This makes it possible
to supply the address and the data simultaneously to
the internal circuit in synchronism with the clock
signal CLK, thereby performing an appropriate data-
25 write operation.

Fig.15 is a circuit diagram showing a
circuit configuration of the latch-input-clock
generator 58.

The latch-input-clock generator 58 of Fig.15
30 includes NAND circuits 221 through 229, inverters 230
through 243, and a plurality of capacitors C.

The data-strobe signal DS1 supplied from the
data-strobe-input buffer 12 is delayed by a series of
delay elements comprised of the inverters 230 through
35 232 and a plurality of the capacitors C. The NAND
circuit 221 and the inverter 237 perform an AND
operation between the delayed and inverted data-strobe

1 signal and the data-strobe signal DS, thereby
generating a pulse signal becoming HIGH at rising
edges of the data-strobe signal DS. This pulse signal
is output as the latch-input clock dslpz via the NAND
5 circuit 228 and the inverter 242 when the frequency-
divided-data-strobe signal ds2x is HIGH. When the
frequency-divided-data-strobe signal ds2x is LOW, on
the other hand, the pulse signal is output as the
latch-input clock ds2pz via the NAND circuit 229 and
10 the inverter 243.

The frequency-divided-data-strobe signal
ds2x becomes HIGH first in response to a first rising
edge of the data-strobe signal DS as shown in Fig.4.
In response to a next rising edge of the data-strobe
15 signal DS, the frequency-divided-data-strobe signal
ds2x changes to LOW. The latch-input-clock generator
58 thus outputs dslpz first, and then outputs ds2pz
one clock cycle later in terms of the clock cycles of
the data-strobe signal DS.

20 The data-strobe signal DS1 input to the
inverter 233 is delayed by a series of delay elements
comprised of the inverters 234 through 236 and a
plurality of the capacitors C. The NAND circuit 222
and the inverter 238 perform an AND operation between
25 an inverse of the data-strobe signal DS1 and the
delayed data-strobe signal, thereby generating a pulse
signal becoming HIGH at falling edges of the data-
strobe signal DS1. This pulse signal is output as the
latch-input clock dslpx via the NAND circuit 226 and
30 the inverter 240 when the frequency-divided-data-
strobe signal ds2x is HIGH. When the frequency-
divided-data-strobe signal ds2x is LOW, on the other
hand, the pulse signal is output as the latch-input
clock ds2px via the NAND circuit 227 and the inverter
35 241.

The frequency-divided-data-strobe signal
ds2x becomes HIGH first in response to a first rising

1 edge of the data-strobe signal DS as shown in Fig.4.
In response to a next rising edge of the data-strobe
signal DS, the frequency-divided-data-strobe signal
ds2x changes to LOW. The latch-input-clock generator
5 58 thus outputs dslpx first, and then outputs ds2px
one clock cycle later in terms of the clock cycles of
the data-strobe signal DS. In this manner, the latch-
input-clock generator 58 outputs pulse signals dslpz,
dslpx, ds2pz, and ds2px successively in this order.

10 The latch-input clocks dslpz and ds2pz
generated as described above are supplied to the data
latches 51 and 54, respectively. In synchronism with
the rising edges of the data-strobe signal DS,
therefore, odd-number input data (D0, D2) as shown in
15 Figs.13 and 14 are latched by the data latches 51 and
54 in turn. Further, the latch-input clocks dslpx and
ds2px are supplied to the data latches 53 and 56,
respectively, so that the even-number input data (D1,
D3) as shown in Figs.13 and 14 are latched by the data
20 latches 53 and 56 in turn in synchronism with the
falling edges of the data-strobe signal DS. By the
same token, the shift registers 52 and 55 store the
even-number data in turn in synchronism with the
falling edges of the data-strobe signal DS. In this
25 manner, the shift register 52, the data latch 53, the
shift register 55, and the data latch 56 respectively
store four pieces of write data D0, D1, D2, and D3
successively in this order as these pieces of data are
supplied serially.

30 Fig.16 is a circuit diagram showing another
configuration of the latch-input-clock generator 58.
The latch-input-clock generator 58 of the figure
includes frequency dividers 541, 542, inverters 543,
544, and AND circuits 545-548.

35 The frequency divider 541 divides by half a
frequency of the data-strobe signal DS1 supplied from
the data-strobe-input buffer 12 to generate the

1 frequency-divided-data-strobe signal ds2x when the
write-enable signal wrtz is HIGH. The AND circuit 545
outputs the data-strobe signal DS1 when the frequency-
divided-data-strobe signal ds2x is HIGH, and supplies
5 a HIGH-level signal dslpz to the data latch 51 in
response to a first rising edge of the data-strobe
signal DS1. The AND circuit 546 outputs the data-
strobe signal DS1 when the frequency-divided-data-
strobe signal ds2x is LOW, and supplies a HIGH-level
10 signal ds2pz to the data latch 54 in response to a
next rising edge of the data-strobe signal DS1.

The frequency divider 542 divides by half a
frequency of the data-strobe signal /DS1 supplied from
the data-strobe-input buffer 12 to generate the
15 frequency-divided-data-strobe signal ds2z when the
write-enable signal wrtz is HIGH. The AND circuit 547
outputs the data-strobe signal /DS1 when the
frequency-divided-data-strobe signal ds2z is HIGH, and
supplies a HIGH-level signal dslpx to the shift
20 register 52 and the data latch 53 in response to a
first falling edge of the data-strobe signal DS1. The
AND circuit 548 outputs the data-strobe signal /DS1
when the frequency-divided-data-strobe signal ds2z is
LOW, and supplies a HIGH-level signal ds2px to the
25 shift register 55 and the data latch 56 in response to
a next falling edge of the data-strobe signal DS1.

In this manner, the latch-input-clock
generator 58 outputs signals dslpz, dslpx, ds2pz, and
ds2px successively in this order in response to the
30 rising edges and falling edges of the data-strobe
signal DS1.

Fig.17 is a circuit diagram showing a
circuit structure of the latch-output-clock generator
59.

35 The latch-output-clock generator 59 of
Fig.17 includes NAND circuit 251 through 255,
inverters 256 through 262, and capacitors C1 and C2.

1 The internal-clock signal iCLK input to the inverter
256 is delayed by a series of delay elements comprised
of the inverters 257 through 259 and the capacitors C1
and C2. The NAND circuit 251 and the inverter 260
5 perform an AND operation between an inverse of the
internal-clock signal iCLK and the delayed internal-
clock signal, thereby generating a pulse signal
becoming HIGH at falling edges of the internal-clock
signal iCLK. This pulse signal is output as the
10 latch-output clock clk1z via the NAND circuits 253 and
255 when the frequency-divided-clock signal clk2z is
HIGH. When the frequency-divided-clock signal clk2z
is LOW, on the other hand, the pulse signal is output
as the latch-output clock clk1x via the NAND circuits
15 252 and 254.

In this example, the frequency-divided-clock
signal clk2z first becomes HIGH and then changes to
LOW, so that the latch-output-clock generator 59 first
outputs clk1z and then outputs clk1x. Accordingly,
20 the shift register 52 and the data latch 53 outputs
the write data D0 and D1, respectively, and, then, the
shift register 55 and the data latch 56 outputs the
next write data D2 and D3, respectively.

As described above, the shift register 52
25 and the data latch 53 (or the shift register 55 and
the data latch 56) need to output the stored data 1.5
clock cycles after the inputting of a corresponding
address. To this end, the second embodiment of the
present invention delays the write-enable signal by
30 one clock cycle by using the delay circuit 57. This
insures that the latch-output-clock generator 59 does
not output clk1z and clk1x at a falling edge of the
internal clock signal iCLK 0.5 clock after the address
input.

35 Fig.18 is a circuit diagram showing another
configuration of the delay circuit 57, the frequency
divider 18, and the latch-output-clock generator 59.

1 The circuit of Fig.18 includes a one-clock
delay 551, a frequency divider 552, inverters 553,
557, and AND circuits 554 and 555. The one-clock
5 delay 551 is comprised of a DQ flip-flop, and delays
the write-enable signal wrtz by one clock cycle,
thereby outputting a signal dwrtz. The frequency
divider 552 is activated by the signal dwrtz, and
divides a frequency of the internal clock signal iCLK
by half to output a frequency-divided-clock signal
10 clk2z. The AND circuit 554 supplies an inverse of the
internal clock signal iCLK as a clk1z signal to the
shift register 52 and the data latch 53 when the
frequency-divided-clock signal clk2z is HIGH. In
other words, the AND circuit 554 outputs the clk1z
15 signal that is HIGH in response to a falling edge of
the internal clock signal iCLK 1.5 clock cycles after
the address corresponding to the first data set (D0,
D1) is acquired. The AND circuit 555 supplies an
inverse of the internal clock signal iCLK as a clk1x
20 signal to the shift register 55 and the data latch 56
when the frequency-divided-clock signal clk2z is LOW.
In other words, the AND circuit 555 outputs the clk1x
signal that is HIGH in response to a falling edge of
the internal clock signal iCLK 1.5 clock cycles after
25 the address corresponding to the second data set (D2,
D3) is acquired. In this manner, the latch-output-
clock generator 59 prompts the shift register 52 and
the data latch 53 to output the data thereof in
parallel at an end of a 1.5-clock-cycle period after
30 the acquisition of the first address, and prompts the
shift register 55 and the data latch 56 to output the
data thereof in parallel at an end of a 1.5-clock-
cycle period after the acquisition of the second
address.

35 The latch-output clock clk1z generated in
such a manner is supplied to the shift register 52 and
the data latch 53, so that the stored data is output

1 to the internal circuit in synchronism with a falling
edge of the clock signal CLK at an end of the 1.5-
clock-cycle period from the inputting of the
corresponding address. Further, the latch-output
5 clock clk1x is supplied to the shift register 55 and
the data latch 56, so that the a falling edge of the
clock signal CLK at an end of a 1.5-clock-cycle period
from the corresponding address input prompts the
outputting of stored data to the internal circuit.

10 Fig.19 is a circuit diagram showing circuit
structures of the data latch 51, the shift register
52, and the data latch 53. The data latch 54, the
shift register 55, and the data latch 56 also have the
same circuit structures as these shown in the figure.

15 The circuit of Fig.19 includes inverters 271
through 282 and transfer gates 283 through 287. Each
of the transfer gates 283 through 287 is comprised of
a PMOS transistor and an NMOS transistor. The
inverters 273 and 274 together make up a latch portion
20 corresponding to the data latch 51, and the inverters
276 and 277 together form a latch corresponding to the
shift register 52. Further, the inverters 280 and 281
together make up a latch portion corresponding to the
data latch 53.

25 Such circuit configuration as shown in
Fig.19 implements operations in which the data latch
51 stores odd-number data (D0) in response to the
latch-input pulse dslpz, and the data latch 53 stores
the even-number data (D1) in response to the latch-
30 input pulse dslpx, while the latch-input pulse also
prompts the shift register 52 to store the odd-number
data transferred from the data latch 51. Further, the
latch-output pulse clk1z is used for outputting the
data to the internal circuit at an appropriate timing,
35 i.e, outputting the data in response to a falling edge
of the clock signal CLK at an end of a 1.5-clock-cycle
period after the acquisition of the corresponding

1 address.

Fig.20 is a circuit diagram showing a relevant portion of the internal-clock generator 60 which generates timing signals clk3az and clk3x used
5 for control of the 1.5-clock-cycle delay.

The circuit of Fig.20 includes NAND circuit 301 and 302, inverters 303 through 311, and a plurality of capacitors C.

The internal clock signal iCLK is delayed by
10 a series of delay elements comprised of the inverters 303 through 305 and a plurality of the capacitors C. The NAND circuit 301 and the inverter 306 performs an AND operation between the delayed and inverted internal clock signal and the internal clock signal
15 iCLK, thereby producing a pulse signal becoming HIGH at rising edges of the internal clock signal iCLK. This pulse signal is output as the timing signal clk3z.

The internal clock signal iCLK input to the
20 inverter 307 is delayed by a series of delay elements comprised of the inverters 308 through 310 and a plurality of the capacitors C. The NAND circuit 302 and the inverter 311 performs an AND operation between an inverse of the internal clock signal iCLK and the
25 delayed internal clock signal, thereby producing a pulse signal becoming HIGH at falling edges of the internal clock signal iCLK. This pulse signal is output as the timing signal clk3x. When the write-enable signal wrtz is LOW, both of the timing signals
30 clk3z and clk3x are LOW. These signals clk3z and clk3x are supplied to the shift register 62.

Fig.21 is a circuit diagram showing circuit structures of the address latch 61, the shift register 62, and the address buffer 28.

35 The circuit of Fig.21 includes inverters 321 through 337 and transfer gates 338 through 343 and 345. Each of the transfer gates 338 through 343 and

1 345 is comprised of a PMOS transistor and an NMOS
transistor. The inverters 323 and 324 together make
up a latch portion corresponding to the address latch
61. Further, a latch comprised of the inverters 326
5 and 327 and a latch formed by the inverters 329 and
330 together form a circuit portion corresponding to
the shift register 62. Further, the inverters 332 and
333 together make up a latch portion corresponding to
the address buffer 28.

10 When the external-timing-pulse signal extpnz
becomes HIGH, the transfer gate 338 opens, so that the
latch comprised of the inverters 323 and 324 latches
the external address signal Add. In response to an
immediately following falling edge of the clock signal
15 CLK, the timing signal clk3x becomes HIGH, so that the
address signal is stored in the latch comprised of the
inverters 326 and 327. Then, the latch comprised of
the inverters 329 and 330 latches the address signal
when a subsequent rising edge of the clock signal CLK
20 is supplied. Finally, in response to a following
falling edge of the clock signal CLK, the address data
stored in the latch is supplied to the address buffer
28.

 When the internal address iAdd is to be
25 stored in the address latch 61 in a burst-write
operation, the internal-timing-pulse signal intpnz
instead of the external-timing-pulse signal extpnz
becomes HIGH. The subsequent operations of the shift
register 62 are the same as described above.

30 The internal address iAdd is generated by
the address generator 25 (Fig.12). The address
generator 25 adds 1 to an address supplied from the
address latch 61 so as to generate the internal
address iAdd.

35 In this manner, the shift register 62
introduces a delay equivalent to 1.5 cycles of the
clock signal CLK. During a read operation, the write-

1 enable signal wrtz becomes LOW, so that the address
latched by the address latch 61 is supplied to the
address buffer 28 via the transfer gate 345 without
incurring an unnecessary delay in the shift register
5 62. That is, only a minimum time period passes from
the input of the read command before the output
becomes available. In this case, the clk3x and clk3z
signals are LOW, thereby preventing the address signal
from passing through the normal path of the shift
10 register 62.

Fig.22 is a circuit diagram showing a
circuit structure of the write-pulse/column-selection-
pulse generator.

This circuit includes OR circuits 611, 612,
15 AND circuits 613, 614, 615, inverters 616, 621, fixed
delays 617 and 618 for timing adjustment, one-clock
delay 619, and a pulse-width adjustment unit 620. A
circuit configuration of this circuit is basically the
same as that of the first embodiment shown in Fig.10.
20 However, the circuit of Fig.10 has the fixed delay 518
receiving the data-strobe signal DS1 while the circuit
of Fig.22 has the fixed-delay circuit 618 which
receives the internal clock signal iCLK. Because of
this difference, the circuit of Fig.22 outputs the
25 write-amplifier-activation signal WRT and the column-
selection pulse csp in synchronism with the internal
clock signal iCLK during the write operation (wrtz: H)
whereas operations of the read operation (wrtz: L) are
identical between the two circuits.

30 Another difference is that the circuit of
Fig.22 is provided with the one-clock delay 619. As
is apparent from Figs.4 and 5, the first write data D0
and D1 are not written in the internal circuit until
at least 1.5 clock cycles after the inputting of the
35 corresponding write command regardless of whether tDSS
is the shortest or the longest. The one-clock delay
619 is provided in order to insure that the write-

1 amplifier-activation signal WRT and the column-
selection pulse csp are not generated prior to a
timing of the falling edge of the internal clock
signal iCLK that corresponds to an end of the 1.5-
5 cycle period.

In the first embodiment previously
described, two address latches (latches 26 and 27) are
provided, whereas the second embodiment is provided
with two sets of data latches. The number of these
10 latches or the number of these data latches is not
limited to two, but, as is apparent from the
disclosure, may be more than two depending on the
length of the longest tDSS.

In the following, third and fourth
15 embodiments will be described.

In the first embodiment, two latches (i.e.,
the latches 26 and 27) are provided for the purpose of
latching addresses. Because of this, the case of the
shortest tDDS as shown in Fig.1 and the case of the
20 longest tDDS as shown in Fig.2 are properly dealt
with. When the two bits (D0, D1) of the first data is
supplied to the internal circuit, it is sufficient in
the case of Fig.1 to have a latch that stores a single
address corresponding to the two-bit data. In the
25 case of Fig.2, however, there is a need to have
latches which store two addresses including a first
address for the first two-bit data and a second
address for second two-bit data. If only one latch is
provided, the case of Fig.2 cannot be handled.
30 Namely, the address for the first two-bit data is
rewritten by the address for the next data as the
first two-bit data is transferred to the internal
circuit, so that writing of data in specified memory
cells cannot be achieved. Further, when the address
35 latches are implemented via shift registers such as
the address latches 61 and 62 of Fig.12, such a
configuration cannot cope with the case of Fig.1.

1 These shift registers perform a data-shift operation
while holding a plurality of consecutive addresses
(two addresses in this example). Because of this, an
address cannot be output to the internal circuit for
5 at least one clock cycle after the acquisition of the
address. Namely, when the first two-bit data is
transferred to the internal circuit, a corresponding
address cannot be output from the shift register to
the internal circuit.

10 The second embodiment is provided with two
parallel sets of data latches (51, 52, 53; 54, 55, 56)
(see Fig.12). This configuration is necessary in
order to cope with a case (Fig.13) in which two sets
of data must remain intact in the storage when the
15 first two-bit data is transferred to the internal
circuit and a case (Fig.14) in which only one set of
data needs to be kept in the storage.

 In the examples of Figs.1 and 2 (or Figs.13
and 14), a description was given with respect to a
20 case in which the margin of the time period t_{DSS} is
equivalent to one clock cycle.

 Fig.23 is a timing chart for explaining
timing relations between the clock signal, the data-
strobe signal, and the data-write timings when the
25 time period t_{DSS} has a narrower margin (e.g.,
equivalent to half the clock cycle).

 As is shown in the example of Fig.23, the
address buffers must keep two addresses stored therein
including an address for first two-bit data and an
30 address for next two-bit data when the first two-bit
data (D0, D1) is transferred to the internal circuit
in parallel. In the example of Fig.23, there is only
one pattern of timing relations as to how the
addresses are acquired. Because of this, a
35 configuration based on the address latch 61 plus the
shift register 62 as described in connection with
Fig.12 can be employed as an address-buffer

1 configuration in place of the configuration using the
latch 26 plus the latch 27 as shown in Fig.3. It
should be noted, however, that the shift register 62
of Fig.12 delays an address signal by 1.5 clock cycles
5 whereas the shift register in the third embodiment
delays an address signal only by one clock cycle.

Fig.24 is a block diagram of the third
embodiment of the present invention. In Fig.24, the
same elements as those of Fig.3 are referred to by the
10 same numerals, and a description thereof will be
omitted.

A semiconductor device 630 of Fig.24
includes the data-input buffer 11, the data latch 14,
the shift register 15, the data latch 16, the write
15 amplifiers 29, 30, the odd-numbered-cell array 36, the
even-numbered-cell array 37, the sense amplifiers 38,
39, the column decoders 40, 41, the read amplifiers
43, 44, the parallel-to-serial conversion unit 503,
the output buffer 504, the data-strobe-input buffer
20 12, the command decoder 22, the write-command latch
23, the mode register 502, the burst-length-
measurement counter 42, the clock generator 501, the
write-pulse/column-selection-pulse generator 31, the
address buffer 13, and the predecoders 34 and 35.

25 The semiconductor device of Fig.24 does not
include the increment latch 24, the address generator
25, the latches 26, 27, the address buffer 28, the
address generator 33, the internal-clock generator 21,
the frequency dividers 17, 18, the latch-input-clock
30 generator 20, and the latch-output-clock generator 19,
all of which are shown in Fig.3. Instead, the
semiconductor device of Fig.24 includes an internal-
clock generator 632 and an address generator 631.

The internal-clock generator 632 has the
35 same configuration as the internal-clock generator 60
of Fig.12, and the address generator 631 has a
configuration that combines the address latch 61, the

1 shift register 62, the address generator 25, and the
address buffer 28 of Fig.12.

With regard to the write-pulse/column-
selection-pulse generator of Fig.24, the AND circuit
5 514 of Fig.10 has one input thereof directly connected
to the write-enable signal wrtz. Instead of this
configuration, this input of the AND circuit 514 may
be connected to the write-enable signal wrtz via such
a one-clock delay as the one-clock delay 619 of
10 Fig.22. In the third embodiment, the first two-bit
data D0 and D1 are not supplied to the internal
circuit until at least one clock cycle after the
inputting of the corresponding write command
regardless of the time period tDSS. It is desirable,
15 therefore, to provide a one-clock-delay circuit in
order to insure that a write pulse/column-selection
pulse is not generated by accident due to noise in the
data-strobe signal DS or the like within one clock
cycle from the inputting of the write command.

20 In this manner, the third embodiment has a
simpler structure than the first embodiment.

Fig.25 is a block diagram of the fourth
embodiment of the present invention.

The second embodiment of Fig.12 is provided
25 with the two sets of data latches so as to satisfy
such timing conditions as required in the case of
Fig.13 and the case of Fig.14. When the tolerable
margin of the time period tDSS is narrower than that
of the second embodiment, there is a case in which it
30 is sufficient for the data latches to hold only the
first two-bit data at a moment when a corresponding
address is output to the internal circuit 1.5 clock
cycles after the acquisition of this address as shown
in Fig.14 regardless of where the actual time period
35 tDSS is located within the tolerable margin. In such
a case, one set of data latches (14, 15, 16) as in
Fig.3 may be used in place of the two sets of data

1 latches (51, 52, 53; 54, 55, 56) as shown in Fig.12.

In Fig.25, the same elements as those of Fig.12 are referred to by the same numerals, and a description thereof will be omitted.

5 A semiconductor device 640 of Fig.25 includes the data-input buffer 11, the write amplifiers 29, 30, the odd-numbered-cell array 36, the even-numbered-cell array 37, the sense amplifiers 38, 39, the column decoders 40, 41, the read amplifiers
10 43, 44, the parallel-to-serial conversion unit 503, the output buffer 504, the data-strobe-input buffer 12, the command decoder 22, the write-command latch 23, the mode register 502, the burst-length-measurement counter 42, the clock generator 501, the
15 write-pulse/column-selection-pulse generator 31, the address buffer 13, the predecoders 34, 35, and the internal-clock generator 60.

The semiconductor device 640 of Fig.25 does not include the data latch 51, the shift register 52,
20 the data latch 53, the data latch 54, the shift register 55, the data latch 56, the delay circuit 57, the frequency dividers 17, 18, the latch-input-clock generator 58, and the latch-output-clock generator 59, all of which are shown in Fig.12. Instead, the
25 semiconductor device 640 includes a serial-to-parallel conversion unit 641 comprised of a data latch 642, a shift register 643, and a data latch 644. The serial-to-parallel conversion unit 641 has the same configuration as the serial-to-parallel conversion
30 unit 505 of the first embodiment shown in Fig.3

In this manner, the semiconductor memory device of the fourth embodiment has a simpler structure than does the second embodiment. In the fourth embodiment, just as in the second embodiment,
35 addresses are acquired in synchronism with the clock signal, and data are acquired in synchronism with the data-strobe signal different from the clock signal,

1 yet the internal circuit of the semiconductor device
processes both the address and the data in synchronism
with the clock signal.

Further, the present invention is not
5 limited to these embodiments, but various variations
and modifications may be made without departing from
the scope of the present invention.

The present application is based on Japanese
priority application No.10-022257 filed on February 3,
10 1998, with Japanese Patent Office, the entire contents
of which are hereby incorporated by reference.

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1 WHAT IS CLAIMED IS

5

1. A semiconductor device which receives addresses in synchronism with a clock signal and receives data in synchronism with a strobe signal, said semiconductor device comprising:

10 address-latch circuits which latches the addresses;

 a first control circuit which selects one of said address-latch circuits in sequence in response to the clock signal, and controls the selected one of
15 said address-latch circuits to latch a corresponding one of the addresses in response to the clock signal; and

 a second control circuit which selects one of said address-latch circuits in sequence in response
20 to the strobe signal, and controls the selected one of said address-latch circuits to output a corresponding one of the addresses in response to the strobe signal.

25

2. The semiconductor device as claimed in claim 1, further comprising data-latch circuits, each of which latches a corresponding datum of the data in
30 synchronism with the strobe signal, and outputs the corresponding datum of the data in synchronism with the strobe signal.

35

3. The semiconductor device as claimed in

1 claim 2, wherein said data-latch circuits operate in
response to a write-enable signal which is generated
in response to a write command to said semiconductor
device.

5

4. The semiconductor device as claimed in
10 claim 3, wherein the write-enable signal controls said
first control circuit and said second control circuit
to operate for a predetermined time period after
receiving the write command.

15

5. The semiconductor device as claimed in
claim 1, wherein said first control circuit includes a
20 first frequency divider configured to divide a
frequency of the clock signal, and selects one of said
address-latch circuits in sequence by using the
frequency-divided clock signal from said first
frequency divider, and said second control circuit
25 includes a second frequency divider configured to
divide a frequency of the strobe signal, and selects
one of said address-latch circuits in sequence by
using the frequency-divided clock signal from said
second frequency divider.

30

6. The semiconductor device as claimed in
35 claim 1, further comprising:

an increment-latch circuit which latches one
of the addresses in synchronism with the clock signal;

1 and

an address-generation circuit which
increments the one of the addresses latched by said
increment-latch circuit by 1, and supplies the
5 incremented address to said address-latch circuits,
wherein each of said address-latch circuits
configured so as to be capable of selecting the
corresponding one of the addresses externally provided
or the incremented address supplied from said address-
10 generation circuit for the latching operation thereof.

15 7. The semiconductor device as claimed in
claim 2, wherein said data-latch circuit comprises:

a first data-latch circuit which latches a
corresponding datum of the data in synchronism with a
rising edge of the strobe signal; and
20 a second data-latch circuit which latches a
corresponding datum of the data in synchronism with a
falling edge of the strobe signal.

25

8. A semiconductor device which receives
addresses in synchronism with a clock signal and
receives data in synchronism with a strobe signal,
30 said semiconductor device comprising:

data-latch circuits;
a first control circuit which selects one of
said data-latch circuits in sequence in response to
the strobe signal, and controls the selected one of
35 said data-latch circuits to latch a corresponding
datum of the data in response to the strobe signal;
and

1 a second control circuit which selects one
of said data-latch circuits in sequence in response to
the clock signal, and controls the selected one of
said data-latch circuits to output a corresponding
5 datum of the data in response to the clock signal.

10 9. The semiconductor device as claimed in
claim 8, further comprising an address-latch circuit
which latches the addresses in sequence in synchronism
with the clock signal, and outputs the addresses in
synchronism with the clock signal.

15

20 10. The semiconductor device as claimed in
claim 8, wherein said address-latch circuit operates
in response to a write-enable signal which is
generated in response to a write command to said
semiconductor device.

25

30 11. The semiconductor device as claimed in
claim 10, wherein the write-enable signal controls
said first control circuit and said second control
circuit to operate for a predetermined time period
after receiving the write command.

35

12. The semiconductor device as claimed in

1 claim 8, wherein said first control circuit includes a
first frequency divider configured to divide a
frequency of the strobe signal, and selects one of
said data-latch circuits in sequence by using the
5 frequency-divided strobe signal from said first
frequency divider, and said second control circuit
includes a second frequency divider configured to
divide a frequency of the clock signal, and selects
one of said data-latch circuits in sequence by using
10 the frequency-divided clock signal from said second
frequency divider.

15 13. The semiconductor device as claimed in
claim 9, further comprising

an address-generation circuit which
increments one of the addresses latched by said
20 address-latch circuit, and supplies the incremented
address to said address-latch circuit,

wherein said address-latch circuit is
configured so as to be capable of selecting the
addresses externally provided or the incremented
25 address supplied from said address-generation circuit
for the latching operation thereof.

30 14. The semiconductor device as claimed in
claim 8, wherein each of said data-latch circuits
includes:

a first latch which latches a corresponding
35 datum of the data in synchronism with a rising edge of
the strobe signal; and

a second latch which latches a corresponding

1 datum of the data in synchronism with a falling edge
of the strobe signal.

5

15. The semiconductor device as claimed in
claim 9, wherein said address-latch circuit includes a
delay circuit which delays output timings of the
10 addresses by a predetermined number of cycles of the
clock signal.

15

16. The semiconductor device as claimed in
claim 1, further comprising an address buffer, wherein
said address-latch circuits supply the addresses to
said address buffer without a clock-cycle delay during
20 a read operation.

25

17. The semiconductor device as claimed in
claim 9, further comprising an address buffer, wherein
said address-latch circuit supplies the addresses to
said address buffer without a clock-cycle delay during
a read operation.

30

18. A memory circuit, comprising:
35 an address-input circuit which latches
address signals in response to a clock signal, and
outputs the address signals in response to a timing

1 signal;

 a data-input circuit which latches data
signals in response to a strobe signal, and outputs
the data signals in response to the timing signal; and

5 an internal circuit which writes the data
signals supplied from the data-input circuit in memory
cells indicated by the address signals supplied from
the address-input circuit.

10

 19. The memory circuit as claimed in claim
18, wherein said timing signal is responsive to the
15 strobe signal.

20 20. The memory circuit as claimed in claim
18, wherein said timing signal is responsive to the
clock signal.

25

 21. The memory circuit as claimed in claim
18, wherein the strobe signal has a cycle identical to
that of the clock signal, and a first timing of a
30 first rising edge of the strobe signal is different
from a second timing of a corresponding rising edge of
the clock signal.

35

 22. The memory circuit as claimed in claim

1 21, wherein the first timing is later than the second
 timing with a timing gap therebetween being shorter
 than one cycle of the clock signal.

5

 23. The memory circuit as claimed in claim
 18, wherein said data-input circuit latches the data
 signals in synchronism with rising edges and falling
10 edges of the strobe signal.

15 24. The memory circuit as claimed in claim
 19, wherein the address-input circuit includes:

 a first latch circuit which latches the
 address signal in response to a first rising edge of
 the clock signal, and outputs the address signal in
20 response to the timing signal; and

 a second latch circuit, connected in
 parallel to the first latch circuit, which latches
 next address signal in response to a next rising edge
 of the clock signal, and outputs the next address
25 signal in response to the timing signal.

30 25. The memory circuit as claimed in claim
 24, wherein the address-input circuit outputs the
 address signal prior to outputting the next address
 signal.

35

1 26. The memory circuit as claimed in claim
19, further comprising:

 a decode circuit which receives the address
signal from the address-input circuit, and decodes the
5 address signal in response to a first activation
signal; and

 a write amplifier which receives the data
signal from the data-input circuit, and amplifies the
data signal in response to a second activation signal
10 in a data-write mode,

 wherein both of the first and second
activation signals are responsive to the strobe signal
in the data-write mode.

15

 27. The memory circuit as claimed in claim
26, wherein in a data-read mode, the first activation
20 signal is responsive to the clock signal, and the
second activation signal is in a deactivated state.

25

 28. The memory circuit as claimed in claim
20, wherein said data-input circuit includes:

 a first data-input circuit which latches the
data signals in sequence in response to a first rising
30 edge and a first falling edge of the strobe signal,
and outputs the data signals in parallel in response
to the timing signal; and

 a second data-input circuit, connected in
parallel to the first data-input circuit, which
35 latches next data signals in sequence in response to a
next rising edge and a next falling edge of the strobe
signal, and outputs the next data signals in parallel

1 in response to the timing signal.

5

29. The memory circuit as claimed in claim
20, wherein said data-input circuit includes a first
data-input circuit which latches the data signals in
sequence in response to a rising edge and a falling
10 edge of the strobe signal, and outputs the data
signals in parallel in response to the timing signal.

15

30. The memory circuit as claimed in claim
29, wherein said first data-input circuit latches next
data signals after outputting the data signals.

20

31. The memory circuit as claimed in claim
28, wherein said data-input circuit outputs the data
25 signals prior to outputting the next data signals.

30

32. The memory circuit as claimed in claim
20, wherein said address-input circuit includes a
shift register which operates in response to the clock
signal.

35

1 33. The memory circuit as claimed in claim
19, wherein said address-input circuit includes a
shift register which operates in response to the clock
signal.

5

10 34. A method of writing data in the memory
circuit of claim 33, comprising a step of adjusting an
input timing of the strobe signal relative to the
clock signal such that said shift register stores two
addresses at a time when the data-input circuit
outputs the data signals.

15

20 35. The memory circuit as claimed in claim
20, further comprising:

a decode circuit which receives the address
signal from the address-input circuit, and decodes the
address signal in response to a first activation
signal; and

25 a write amplifier which receives the data
signal from the data-input circuit, and amplifies the
data signal in response to a second activation signal
in a data-write mode,

30 wherein both of the first and second
activation signals are responsive to the clock signal
in the data-write mode.

35

36. The memory circuit as claimed in claim
35, wherein in a data-read mode, the first activation

1 signal is responsive to the clock signal, and the
second activation signal is in a deactivated state.

5

37. The memory circuit as claimed in claim
26, wherein in the data-write mode, the first
activation signal activates said decode circuit after
10 said address-input circuit outputs the address
signals, and the second activation signal activates
said write amplifier after said data-input circuit
outputs the data signals.

15

38. The memory circuit as claimed in claim
35, wherein in the data-write mode, the first
activation signal activates said decode circuit after
20 said address-input circuit outputs the address
signals, and the second activation signal activates
said write amplifier after said data-input circuit
outputs the data signals.

25

39. The memory circuit as claimed in claim
30 32, wherein said shift register delays the address
signals by 1.5 clock cycles of the clock signal.

35

40. The memory circuit as claimed in claim
18, wherein a timing at which said address-input

1 circuit outputs the address signals is concurrent with
a timing at which said data-input circuit outputs the
data signals corresponding to the address signals.

5

41. The memory circuit as claimed in claim
32, further comprising a bypass circuit provided in
10 parallel to said shift register, wherein the address
signals pass through the bypass circuit and bypass
said shift register in a data-read mode.

15

42. The memory circuit as claimed in claim
33, further comprising a bypass circuit provided in
parallel to said shift register, wherein the address
20 signals pass through the bypass circuit and bypass
said shift register in a data-read mode.

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FIG. 1

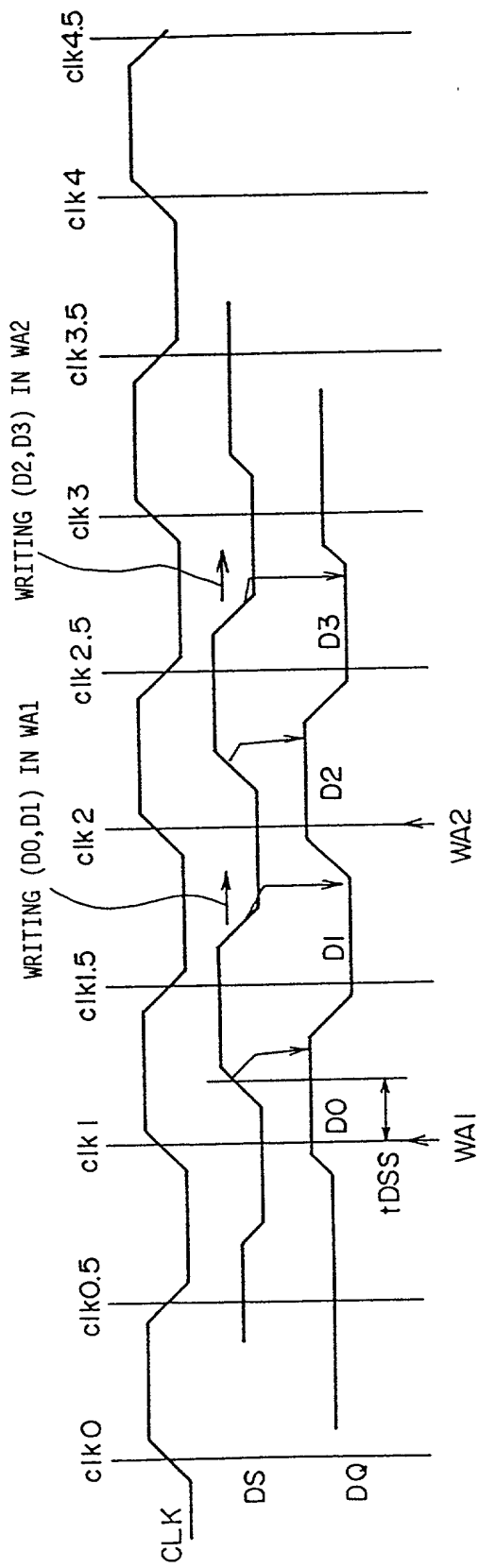


FIG. 2

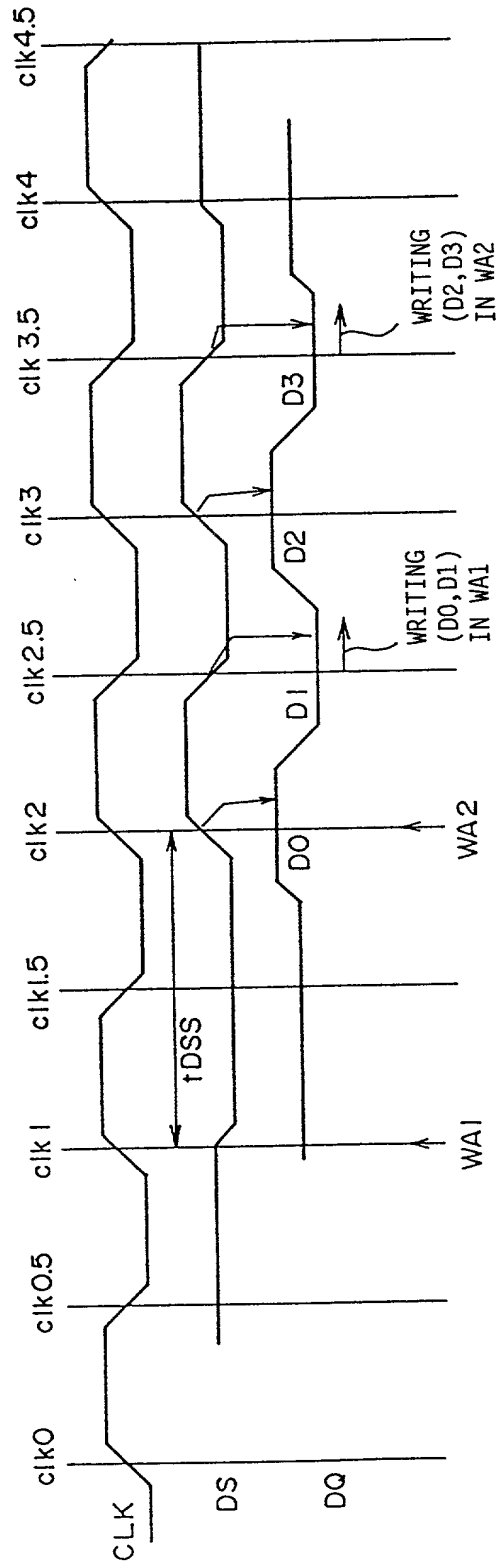


FIG. 3

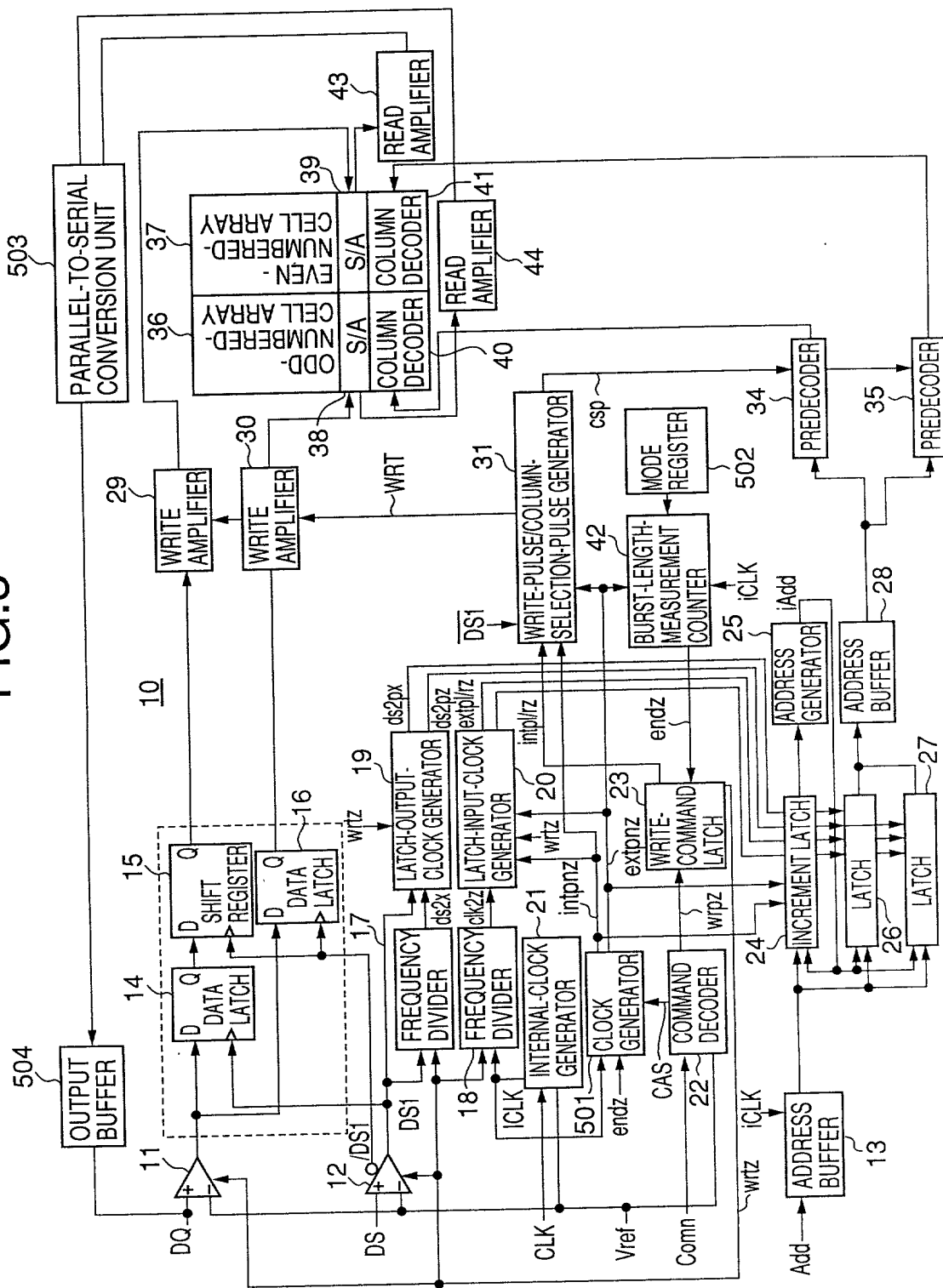


FIG. 4A

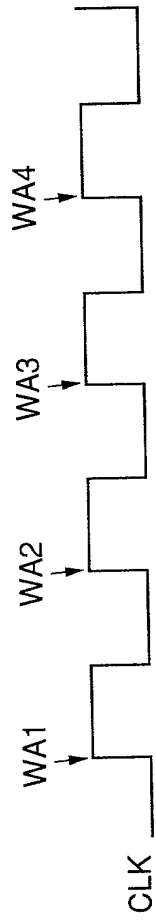


FIG. 4B

clk2z

FIG. 4C

extpnz

FIG. 4D

extprz

FIG. 4E

extplz

FIG. 4F

DS

FIG. 4G

ds2x

FIG. 4H

ds2px

FIG. 4I

ds2pz

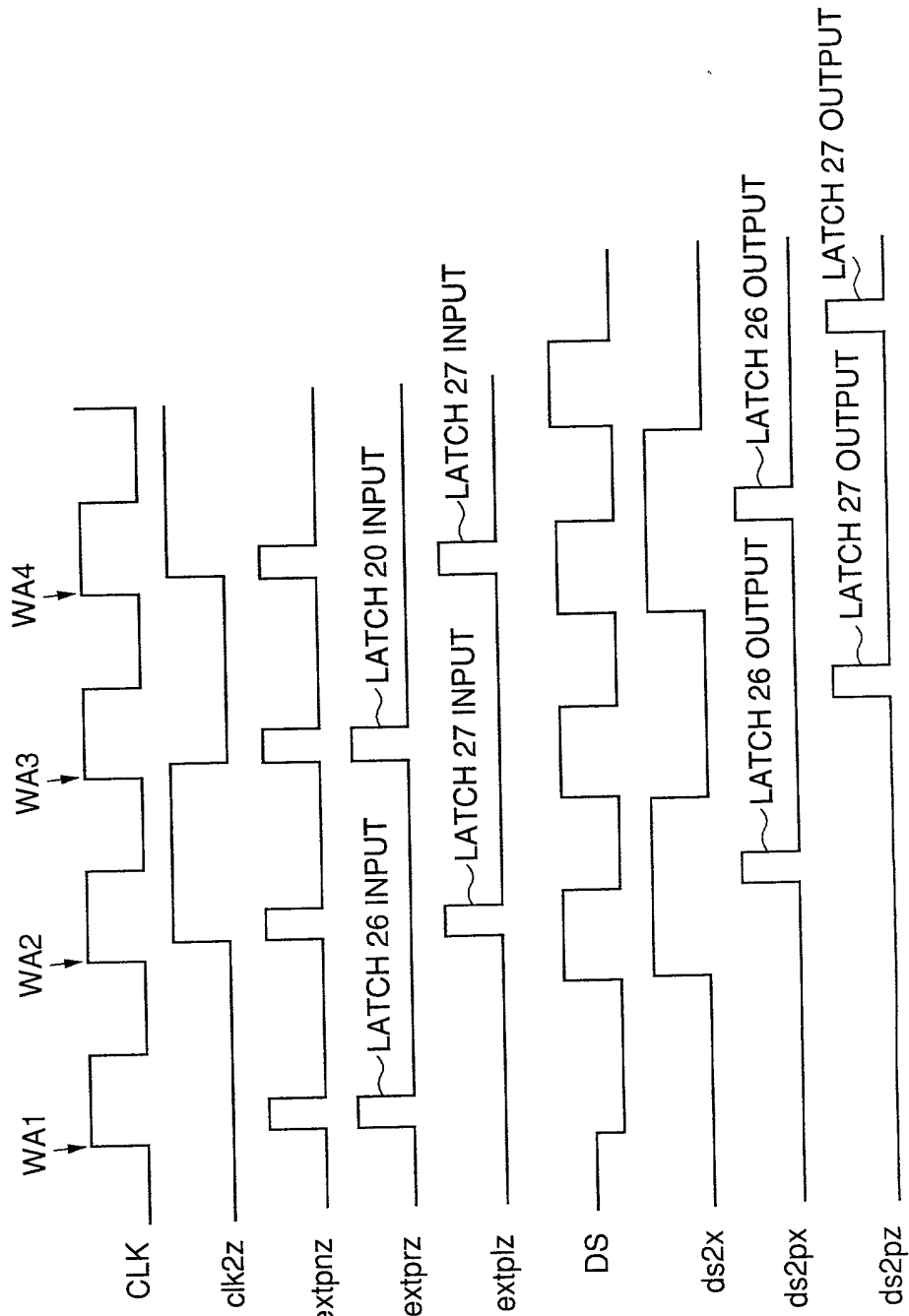


FIG.5

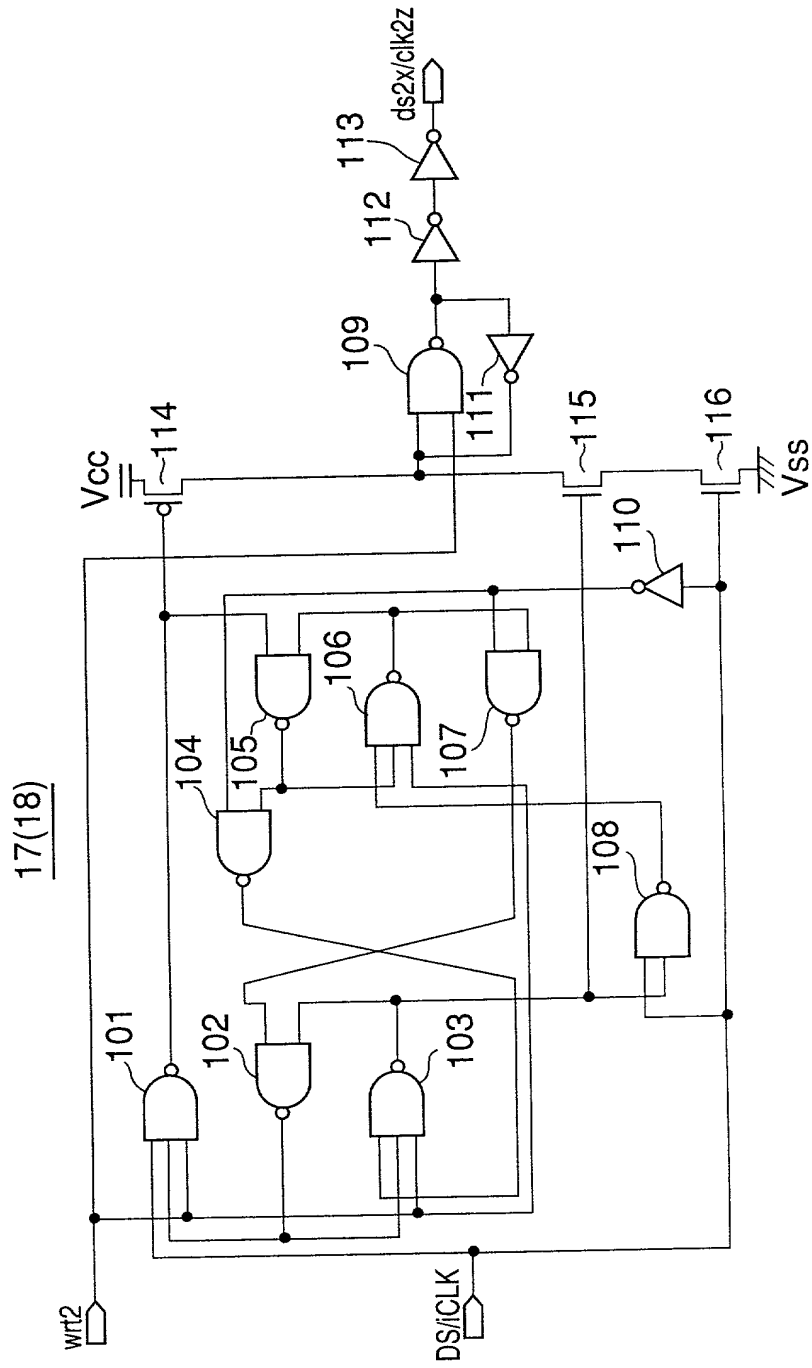


FIG. 6

20

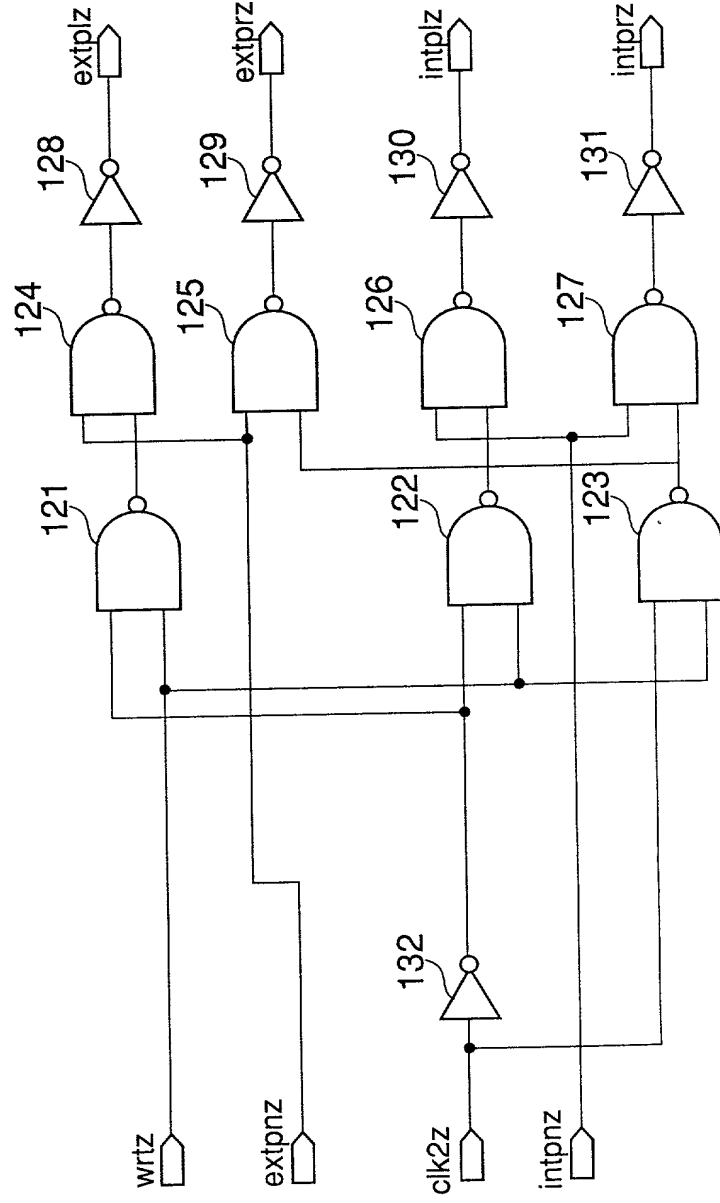


FIG. 7

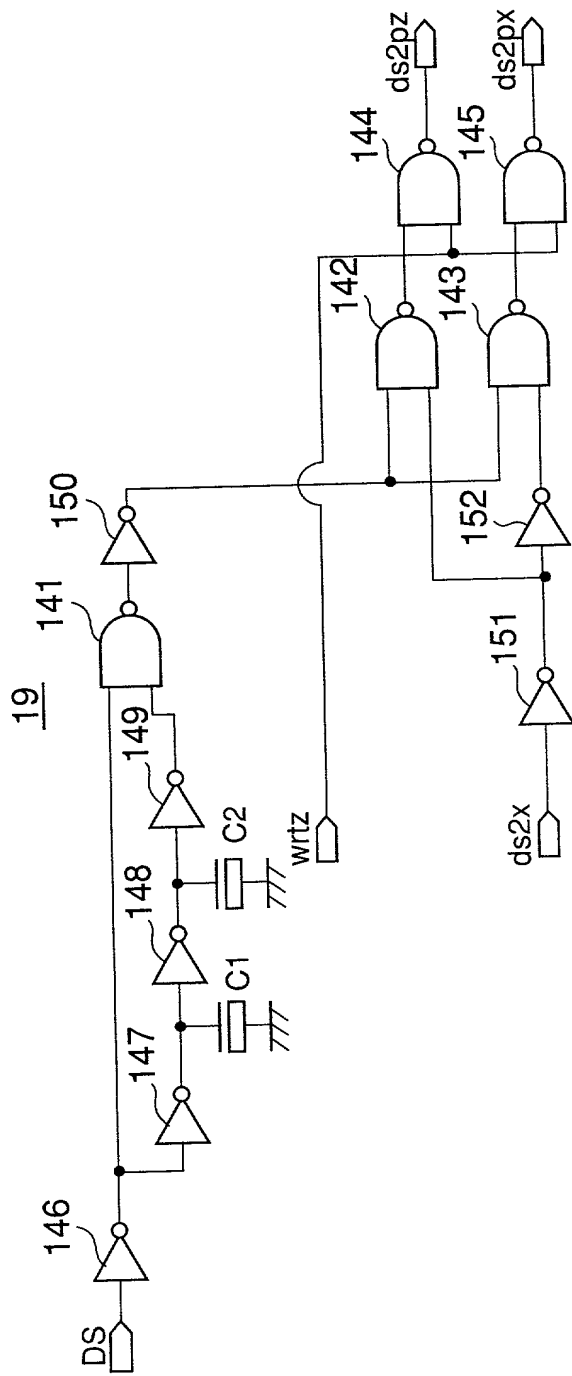


FIG. 8

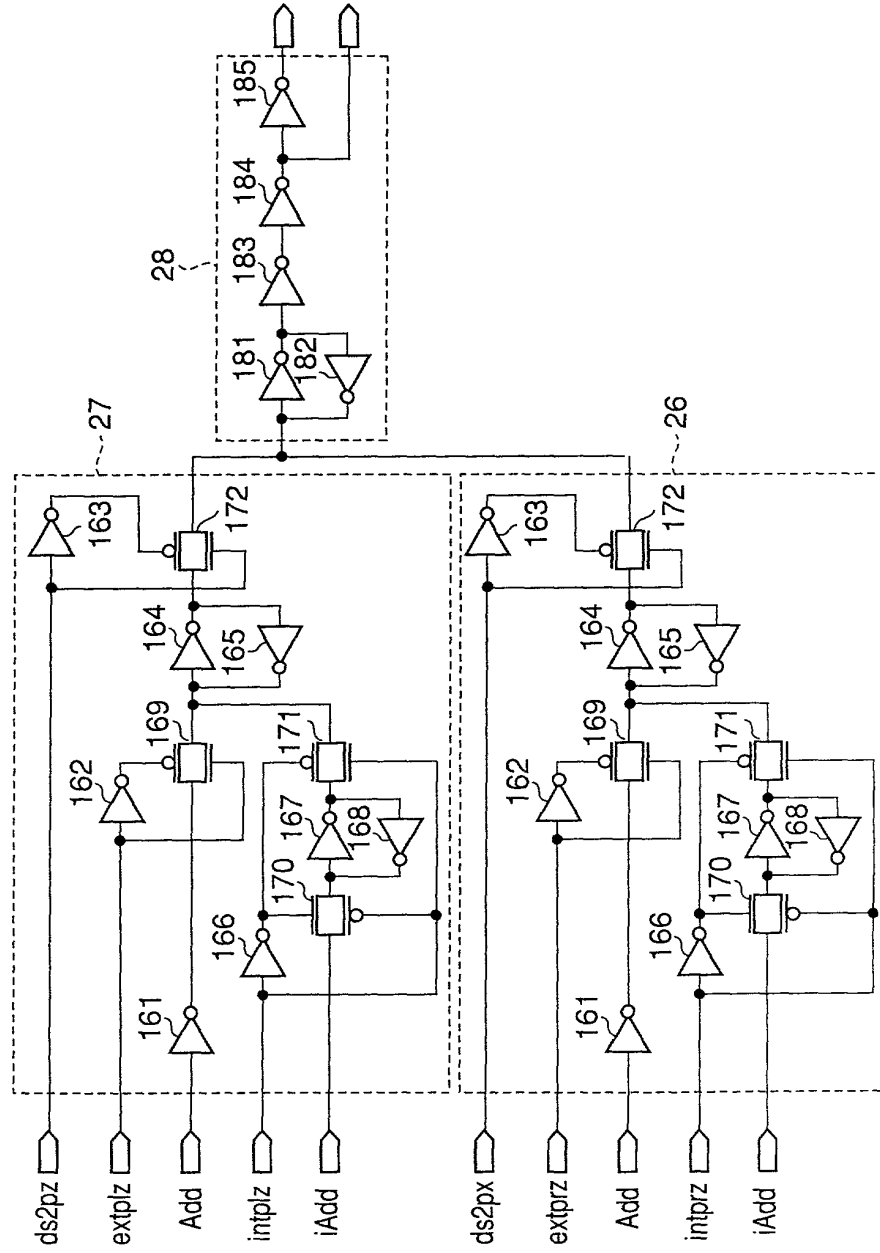


FIG.9

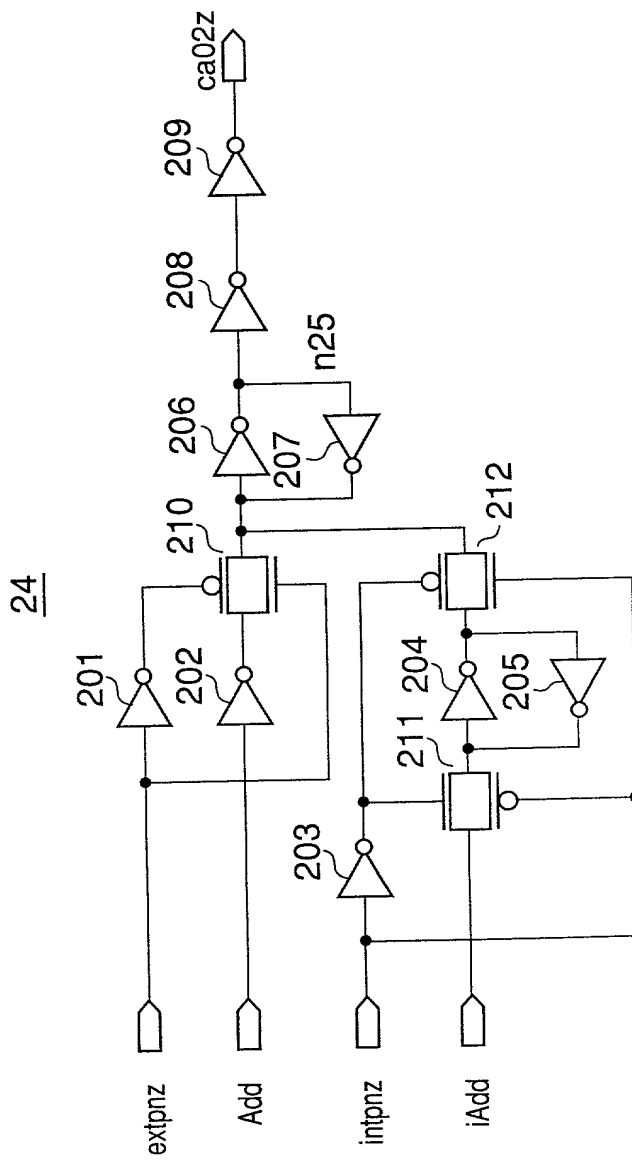


FIG.10

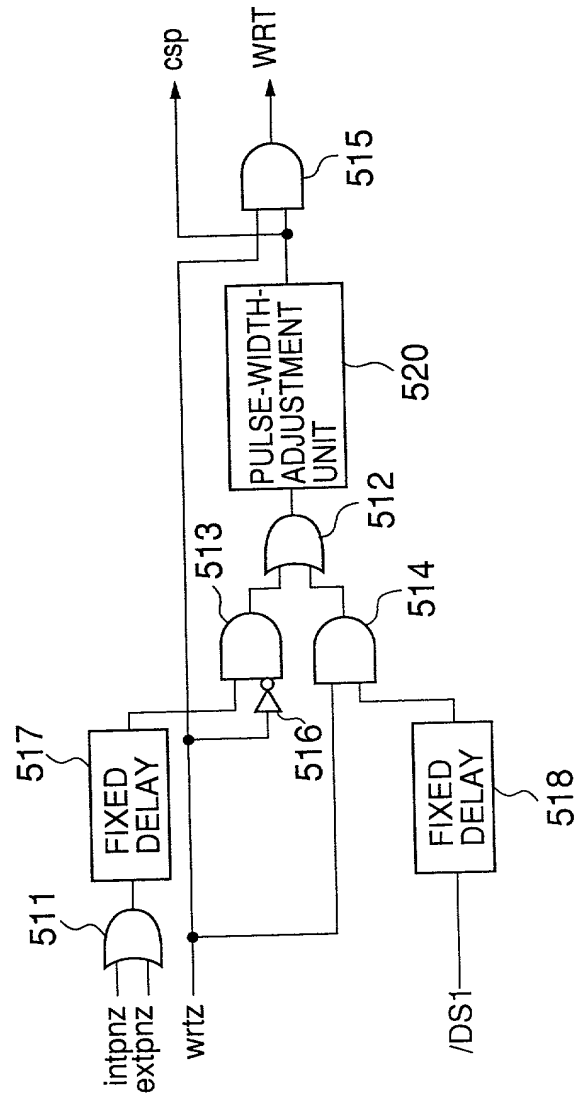
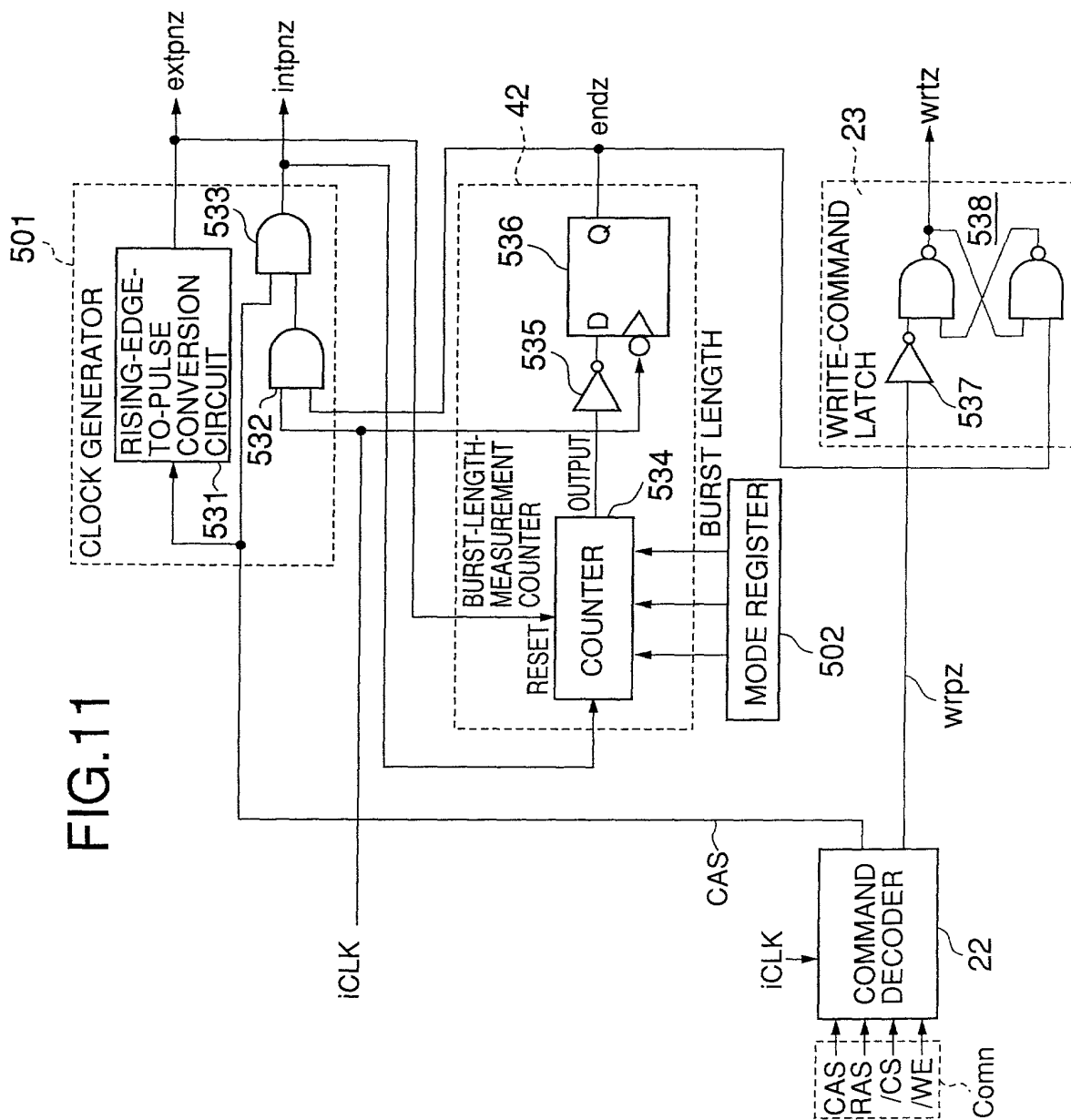


FIG.11



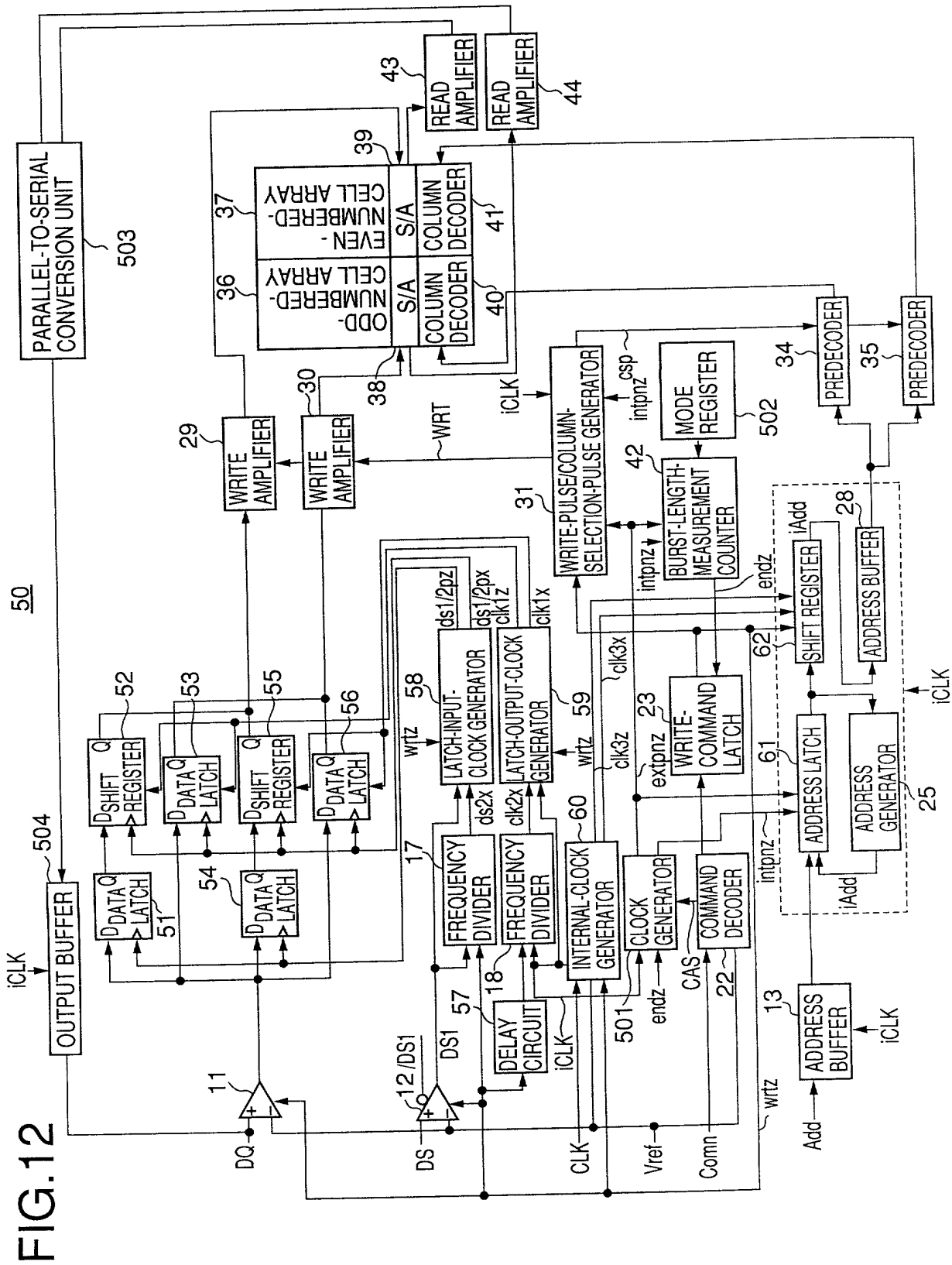


FIG. 13

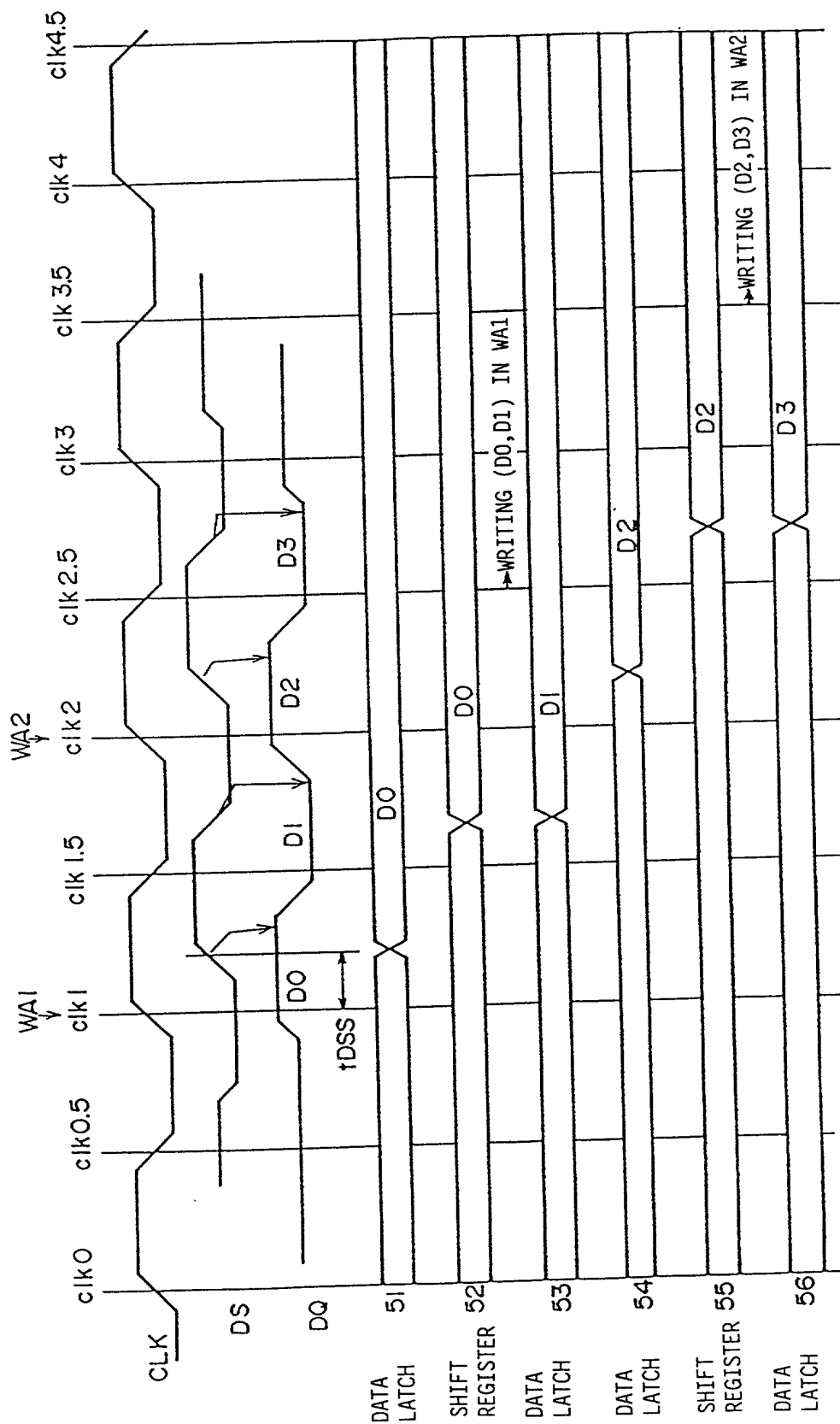


FIG. 14

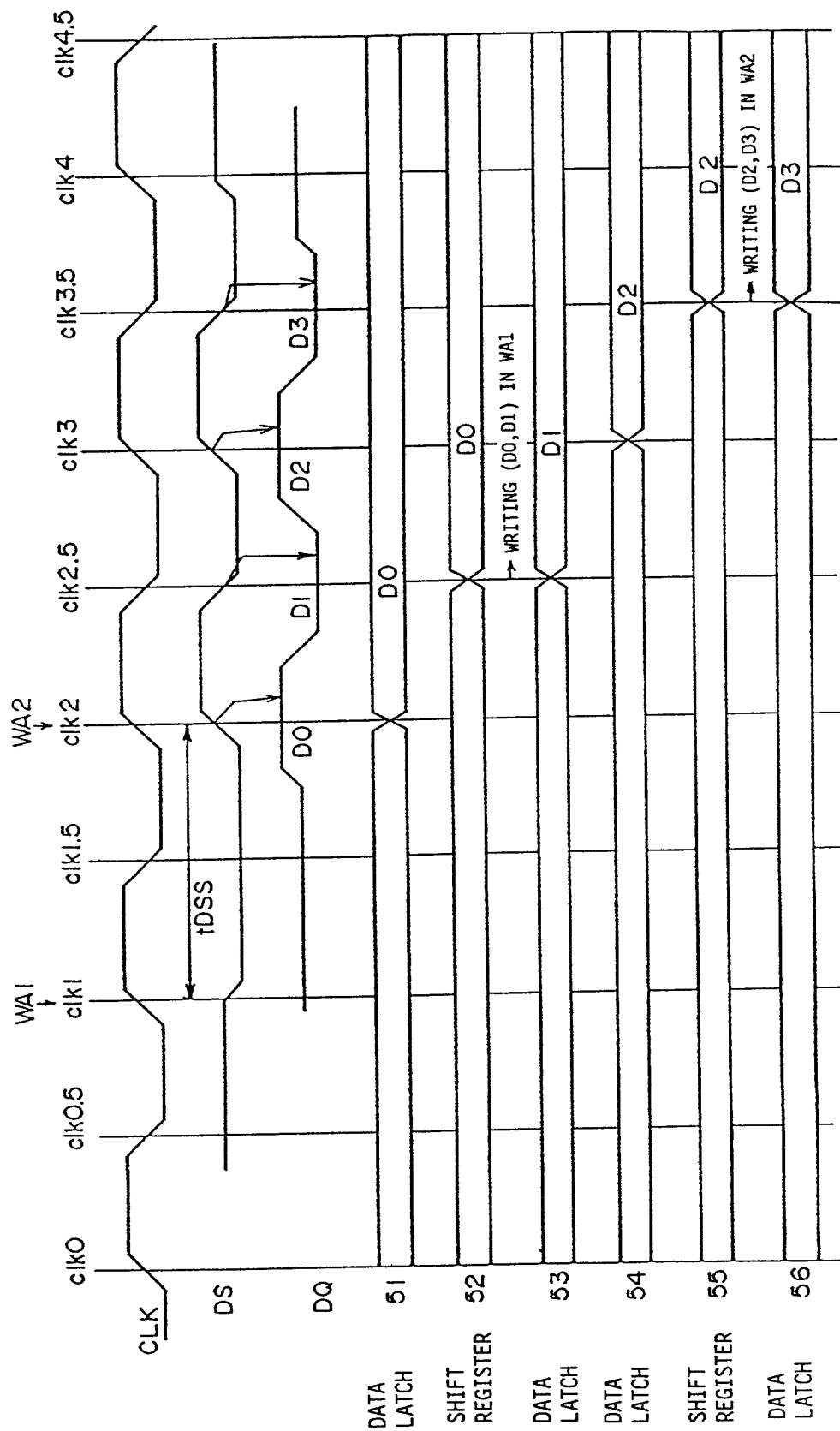


FIG. 15

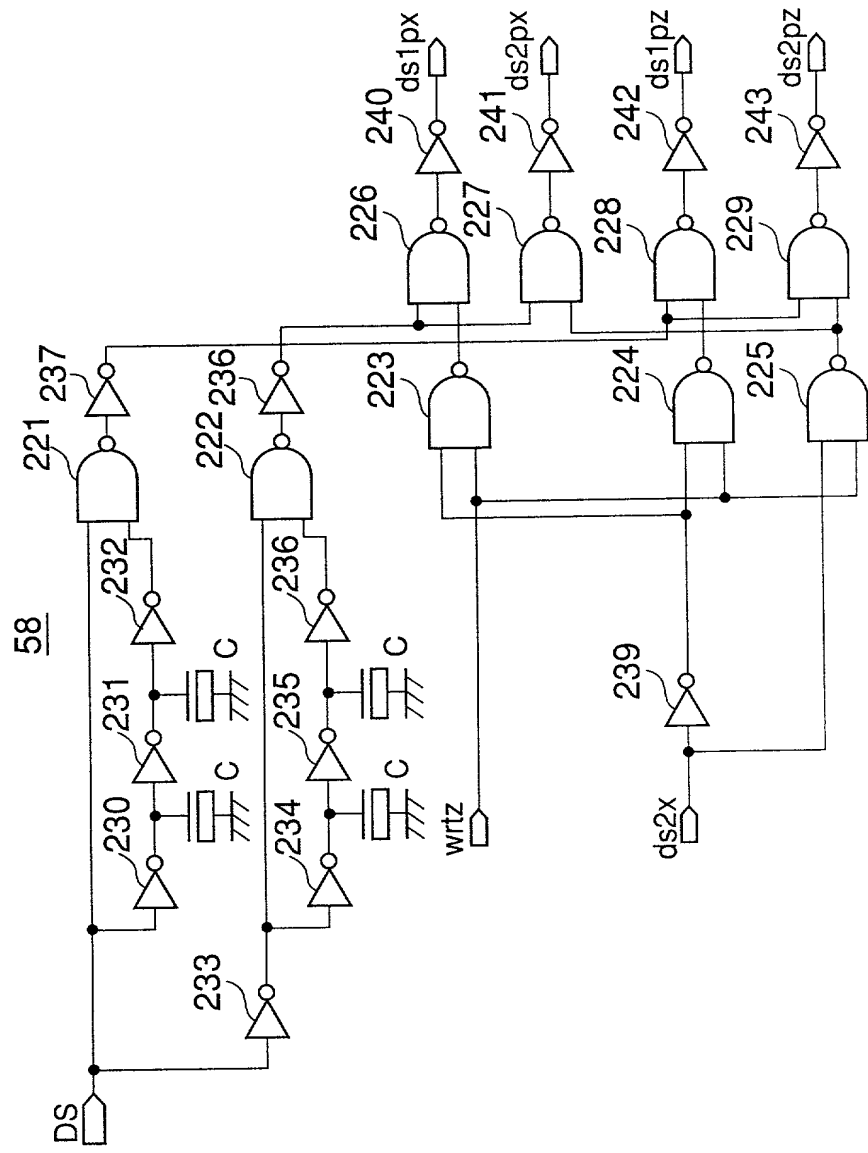


FIG.16

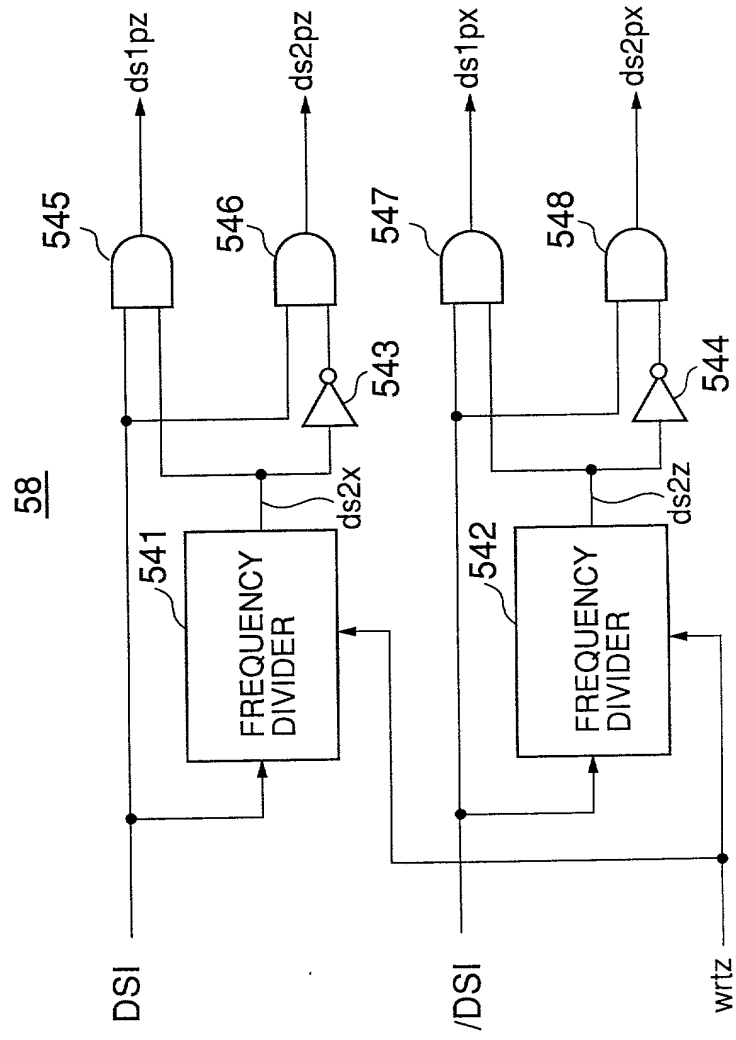


FIG.17

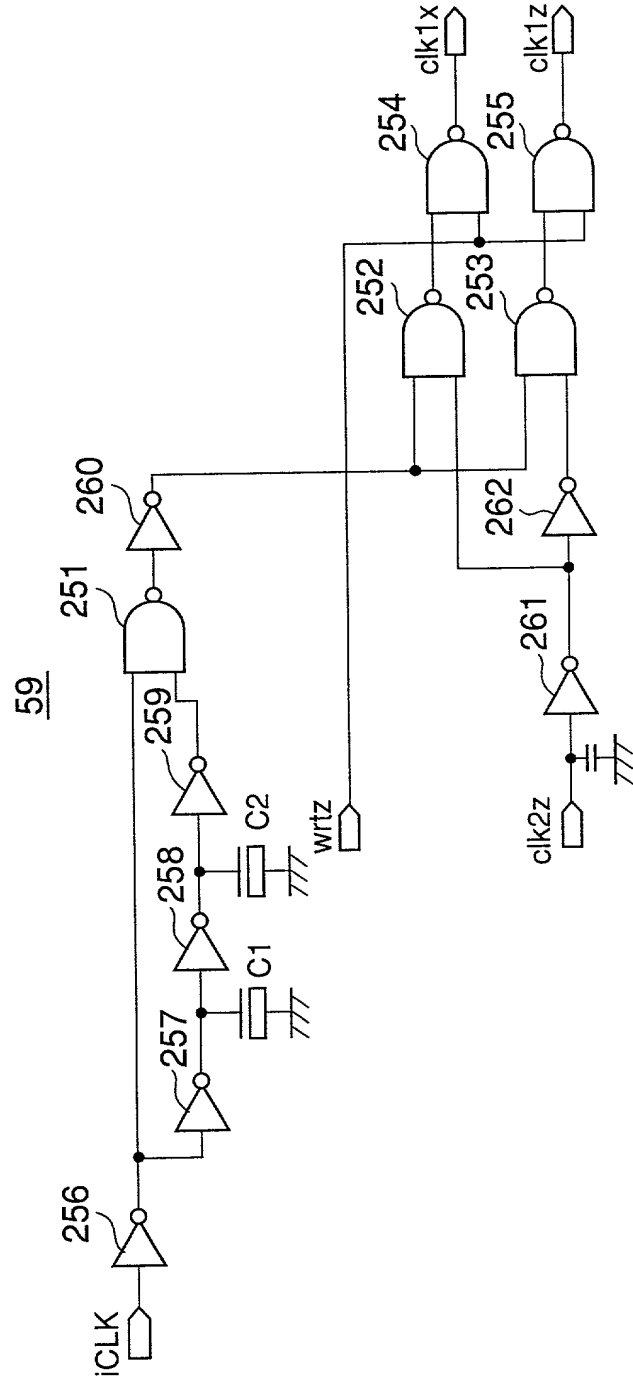


FIG.18

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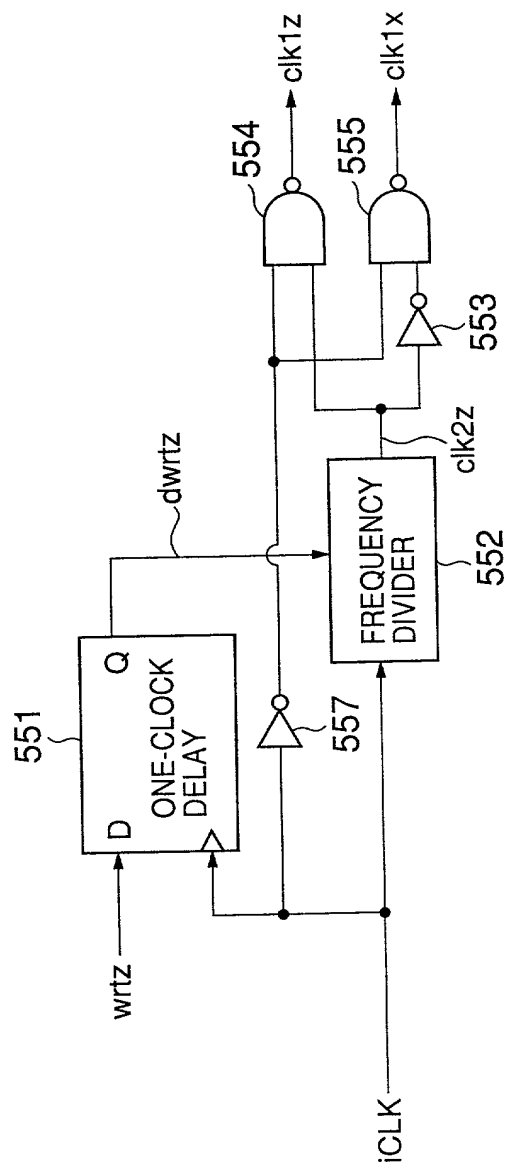


FIG.19

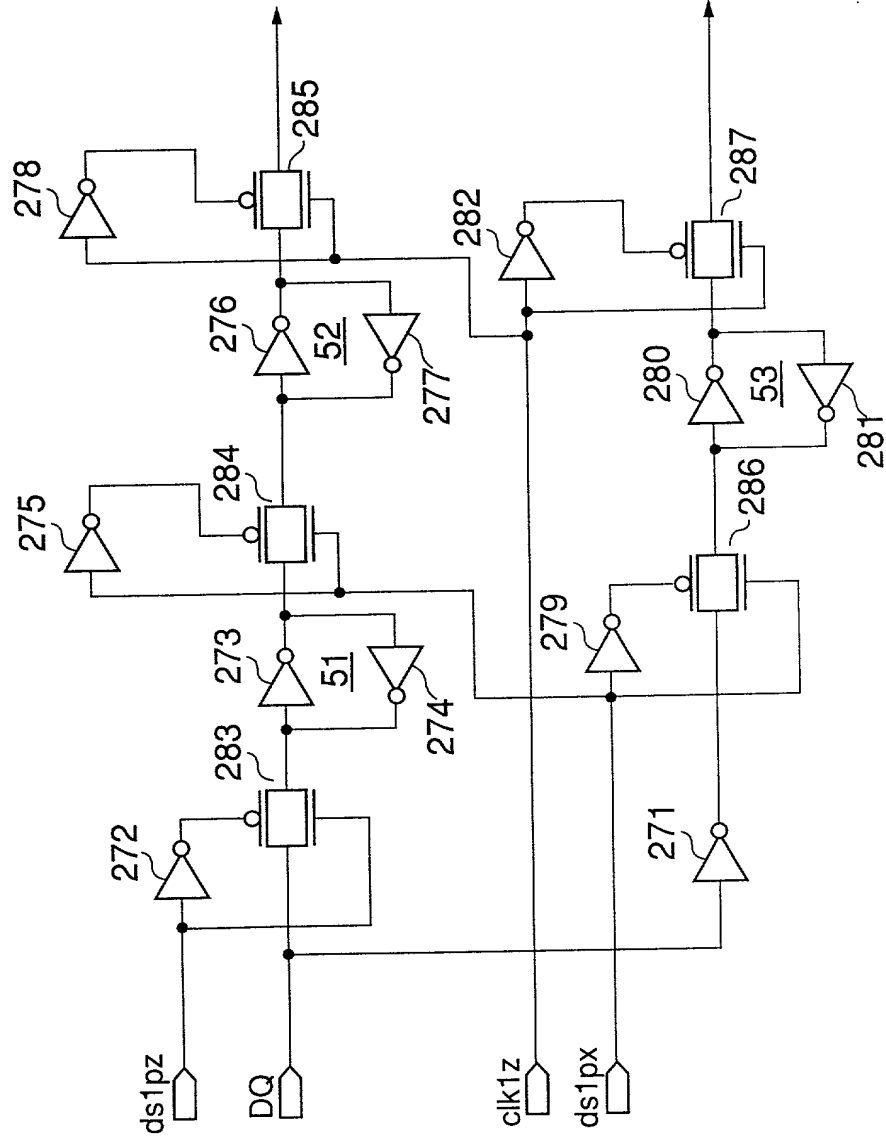


FIG.20

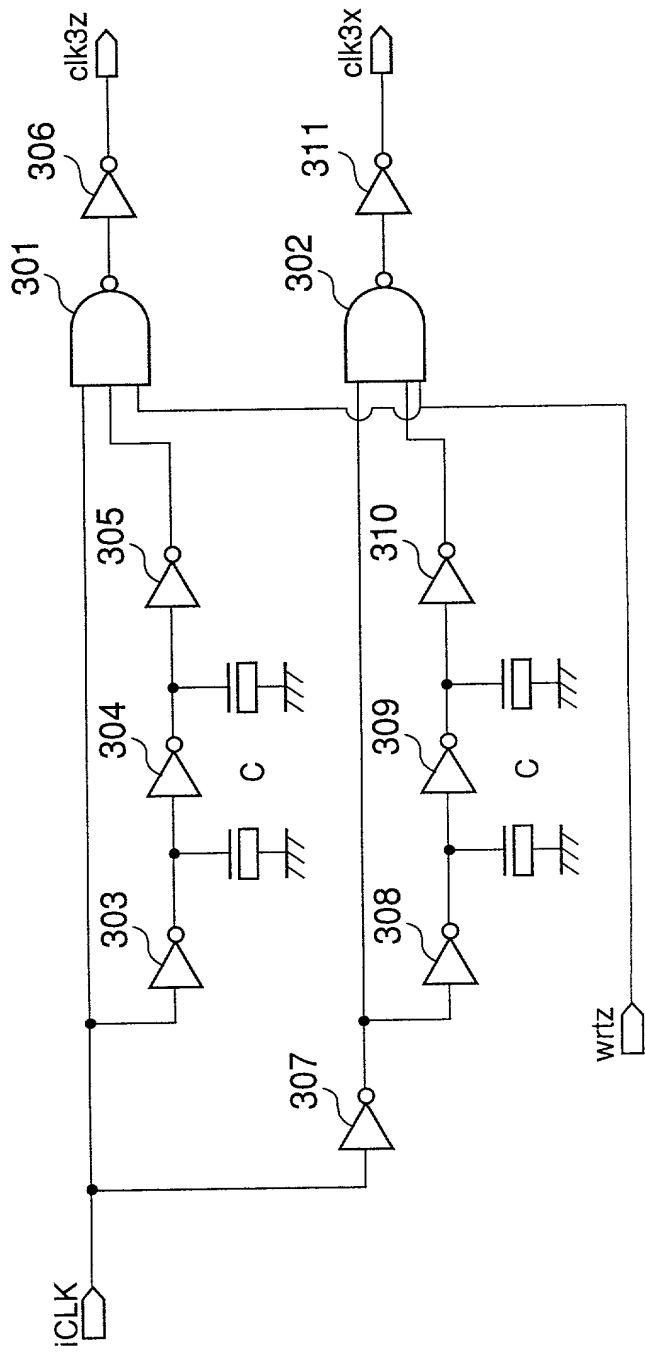


FIG.21

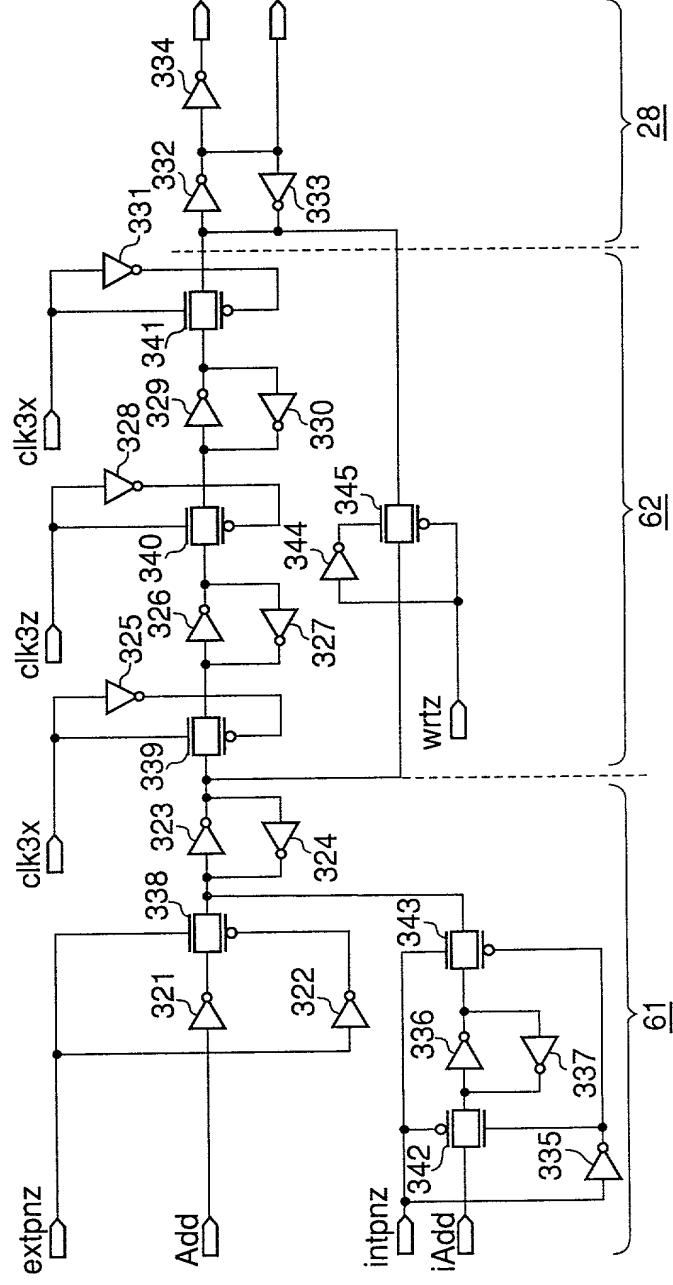
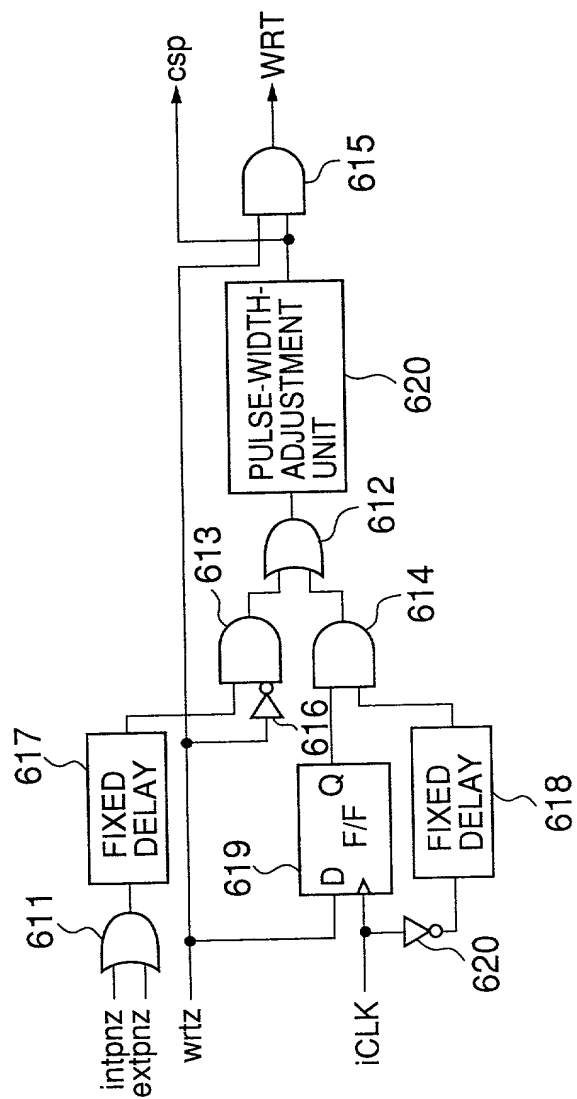
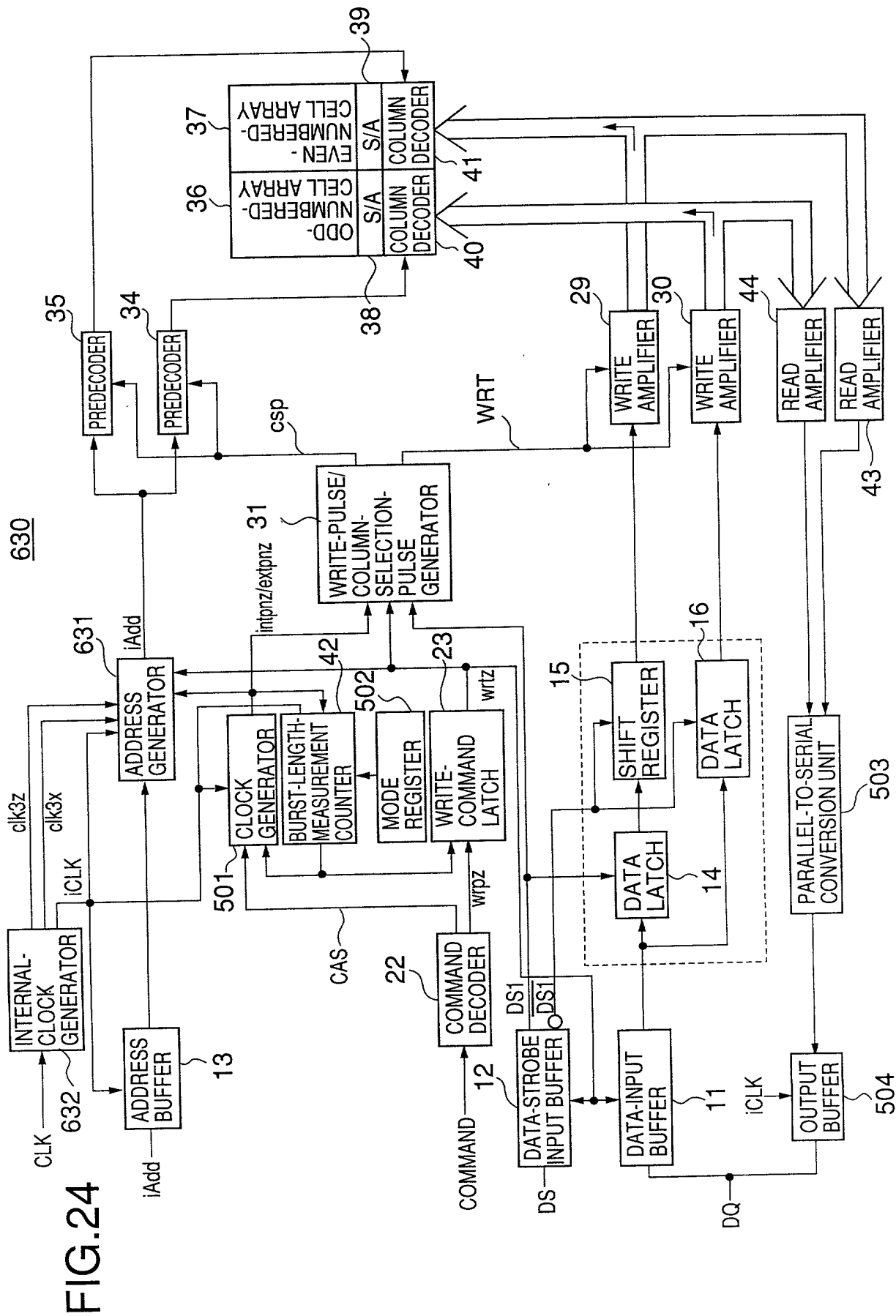
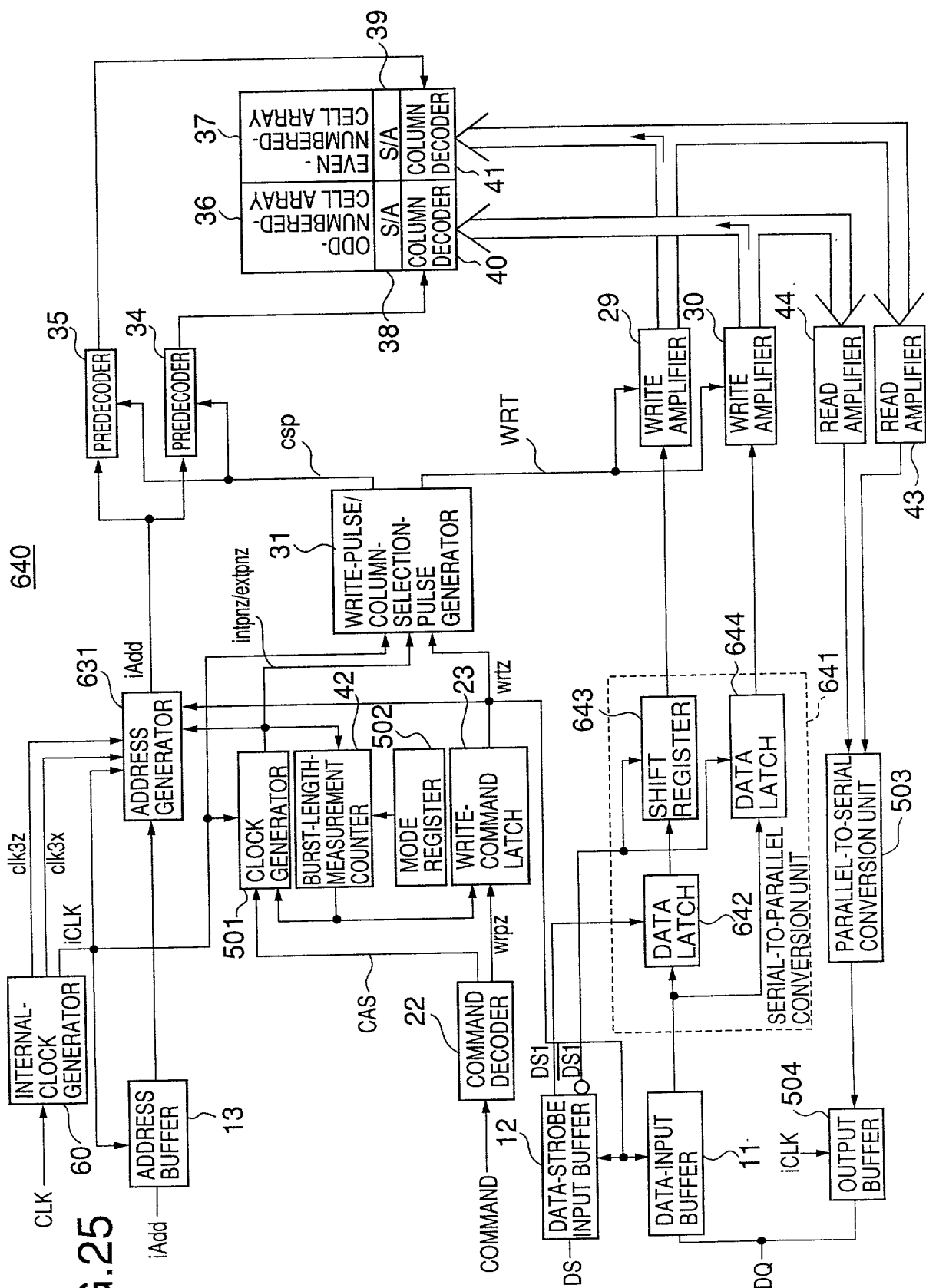


FIG. 22







N, M, M & O Docket No. _____

NIKAIDO, MARMELESTEIN, MURRAY & ORAM LLP

Declaration For U.S. Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
(Insert Title) SEMICONDUCTOR DEVICE RECONCILING DIFFERENT TIMING SIGNALS

the specification of which

(Check one
of blocks
1, 2 or 3.
See note A
on back of
this page)

1. ☒ is attached hereto.
2. ☐ was filed on _____ as
International PCT Application Serial No. _____
and was amended on _____
(if applicable)
3. ☐ was filed on _____ as
U.S. Application Serial No. _____
and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application for which priority is claimed:

Pat.	Appln. No.	Japan	3/February/1998	Priority Claimed
(List prior foreign applications. See note B on back of this page)	(Number)	(Country)	(Day/Month/Year Filed)	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
	(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No
	(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No

(See Note C on back of this page) ☐ See attached list for additional prior foreign applications

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(List prior U.S. Applications)	(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
	(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

And I hereby appoint as principal attorneys David T. Nikaido, Reg. No. 22,663; Charles M. Marmelstein, Reg. No. 25,895; George E. Oram, Jr., Reg. No. 27,931; Robert B. Murray, Reg. No. 22,980; Martin S. Postman, Reg. No. 18,570; E. Marcie Emas, Reg. No. 32,131; Douglas H. Goldhush, Reg. No. 33,125; Kevin C. Brown, Reg. No. 32,402; Monica Chin Kitts, Reg. No. 36,105; Sharon N. Klesner, Reg. No. 36,335 and Richard J. Berman, Reg. No. 39,107.

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Metropolitan Square
655 Fifteenth Street, N.W., Suite 330 - G Street Lobby
Washington, D.C. 20005-5701
(202) 638-5000 Fax: (202) 638-4810

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

(See Note D
on back of
this page)

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Inventor's signature Hirovoshi Tomita Jan. 25, 1999
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Citizenship Japan
Post Office Address c/o FUJITSU LIMITED, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa, 211-8588 Japan

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Kawasaki-shi, Kanagawa, 211-8588 Japan

Full name of third joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of fourth joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of fifth joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of sixth joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of seventh joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of eighth joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

Full name of ninth joint inventor, if any _____

Inventor's signature _____ Date

Residence _____

Citizenship _____

Post Office Address _____

2000042500